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AN INTERMEDIATE LANGUAGE AND INTERPRETER FOR THE ASGOL GRAPHICS--ETC(U)
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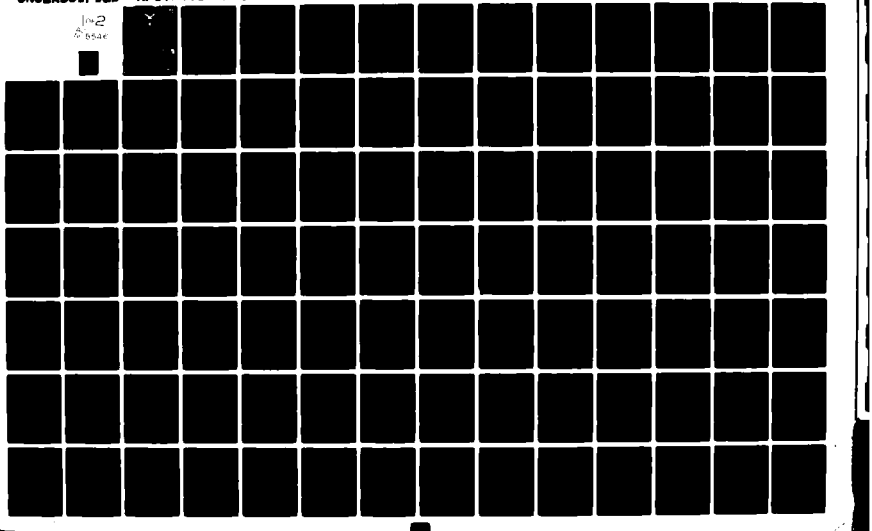




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# AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

# An Intermediate Language and Interpreter for the ASGOL Graphics Language

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# An Intermediate Language and Interpreter for the ASGOL Graphics Language

Thesis

Presented to the Faculty of the School of Engineering
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Master of Science

by
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Graduate Computer Systems
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## Preface

The construction of languages and compilers has always been an area of fascination for me. It is not surprising, then, that when the opportunity to do this thesis presented itself I did not hesitate.

I would like to take this opportunity to thank Major Michael C. Wirth for his support as my advisor on this thesis project. I would also like to thank Professor Charles Richard and Captain Roie Black for their ideas and comments. In addition I would like to thank Mike Luthman of AFWAL/ACD for his comments during the preparation of the users manual.

Finally, I would especially like to thank my wife Beth for her understanding and support during the course of the project. Without her encouragement the project would never have been completed on time.

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## Abstract

In an effort to make ASGOL (ALGOL-Structured Graphics Oriented Language) more powerful, conditional and looping instructions were added to the language. To do this the existing interpreter system was converted to a compiler/interpreter system. An intermediate language was designed as the compiler output and thus the source language for the interpreter.

# An Intermediate Language and Interpreter for the ASGOL Graphics Language

## I. Introduction

Anyone who has had a large amount of data to analyze is well aware that computer graphics is a very powerful tool. Not only is much time saved by having the computer do most of the processing, but by using a graphic format the results are presented in a clear, concise form. This is particularly important for any manager or commander who needs those results to make critical decisions.

Thus, there is a need for graphics that can be produced quickly and accurately with a minimum of effort. However, the people who possess the detailed knowledge and training for this job are not always available, leaving the responsibility for the creation of meaningful products to people with little knowledge of computers or graphics. Therefore, various graphic packages have evolved to simplify this process while still giving the desired results.

The Air Force Wright Aeronautical Laboratory (AFWAL/ACD) recognized the need for a management graphics system to interface with the Display Integrated Software System and Plotting Language (DISSPLA) graphics package (Ref 1) that is now being used. DISSPLA is a very complex system and requires a FORTRAN program to make it work. Unfortunately, the office in AFWAL that uses the system has no full time programmers. Therefore, it was essential that an easier way of using the system be found.

To solve this problem the lab sponsored a thesis by Lieutenant James D. Hart (Ref 2). The goal of Hart's effort was to develop a system that would be easily readable and easily used by anyone without a detailed understanding of FORTRAN or the DISSPLA system. In that thesis Lt. Hart designed a language (ASGOL) and set up an interpreter system to execute it.

## Problem and Scope

There are two problems with Lt. Hart's system. The first and most important deals with its structure. Each instruction is executed and discarded as soon as it is decoded, leaving no way for conditional and looping type structures to be implemented. Since these structures are useful, this thesis effort involved the redesign of ASGOL and the interpreter system to include them. With the

exception of some simplification of ASGOL, only those changes necessary to implement the desired instructions were done.

The second problem involves the size of the system. Due to the large size requirements of DISSPLA, this system cannot be run interactively. As this was one of the sponsor's requirements, this problem was investigated.

## Assumptions

The two major parts of the system, the LR(1) parser and the DISSPLA graphics system, were kept with few changes. It was accepted that a table driven LR(1) parser and the DISSPLA graphics package were the best tools available. Therefore, no attempt was made to identify or implement a replacement for either one.

## Approach

The first step in this thesis effort was to identify the most useful conditional and looping structures. Then, in order to implement them within ASGOL, an intermediate language (AIL) was designed. This allowed the execution of the program to be delayed until after all the instructions had been decoded.

Two major changes were then made to the system to incorporate AIL. First the parser had to be modified to produce the appropriate AIL commands as the program instructions were decoded. After this was done it was necessary to design and implement a new interpreter to execute AIL and produce the plots. These modifications effectively changed the ASGOL system from a direct interpreter to a compiler/interpreter combination.

## Organization

Included in the remainder of this thesis is a discussion of the requirements and specifications of the system (Chapter II) and a discussion of ASGOL (Chapter III).

Chapter IV describes the scanner and the parser while Chapter V covers AIL and its interpreter. Chapter VI is included to provide an analysis of the applications of the system. Finally, Chapter VII gives conclusions and recommendations for enhancements.

Several appendices are also included to provide more detailed information. Appendix A is a listing of the formal definition of ASGOL and Appendix B lists the AIL statements. Appendix C then details the steps involved in each production of the looping and control statements. Appendices D and E describe the software modules associated with the scanner, the parser, and the interpreter. With

Appendices A, B and C they make up a maintenance manual for the system. Finally a users manual is included as Appendix F.

## II. Requirements and Specifications

### User Requirements

Once a month AFWAL/ACD, the thesis sponsors, generate a Commander's report (a series of graphs and tables) that currently is created in part using the DISSPLA system. The tables, however, are done by hand. The ASGOL system was designed to generate the appropriate DISSPLA commands to allow the entire report to be created using the CDC CYBER computer. In performing this function it was requested that the ASGOL system have the following characteristics:

1. easily used,
2. capable of using data from user specified files,
3. capable of running selected parts of the report,
4. capable of graphics blow-up.

The ease of use requirement was met by designing ASGOL as a high-level language. This allowed it to be made machine independent and thus requires no specific knowledge of any computer system by the user. In addition, ASGOL was made free format to allow a user complete freedom to organize the program in a clear, meaningful manner. Perhaps more important to this requirement, though, was the incorporation in ASGOL of as many English language instructions as possible. A user needs only to state what

is wanted and does not have to worry about the translation of terms into DISSPLA commands. For example, the specification of plot type is done simply by naming the type desired; LINEAR, BAR, PIE, etc. ASGOL keeps track of the relationship of these terms to their DISSPLA routines. See Chapter 3 for more detail on the structure of ASGOL.

The capability to use data from user specified files was incorporated into ASGOL through the use of the INPUT instruction. This instruction allows the source tape number to be specified when the program is written making any data file available to the system.

The last two capabilities, running selected parts and graphic blow-up, are available in the DISSPLA Post Processor System (Ref 3). Therefore no special action was taken in the ASGOL system to duplicate any of these functions. The following description of the DISSPLA system will discuss these functions in more detail.

## DISSPLA Requirements

The DISSPLA graphic system consists of a number of integrated subroutines that create a device independant plot file. On the CYBER these routines are written in FORTRAN IV and thus they require any program that calls them to be written in the same language. Any other language (PASCAL,

FORTRAN V, FORTRAN 77, etc.) will not work because the I/O done by the DISSPLA routines will have unpredictable results (Ref 4). It was this fact that placed probably the most severe restriction on the ASGOL system. By forcing the system to be written in FORTRAN IV all of the convenience and power of the other languages was unavailable, resulting in a needlessly complex system.

To create a plot DISSPLA requires that information be specified in four areas: page size, axis lengths, origin, and step sizes. These areas must be specified in the order listed since each depends on the information in the areas preceeding it (Ref 2: Part A 3-1). It is ASGOL's responsibility to ensure that all needed information is specified in the correct order as the user is not required to have an understanding of the DISSPLA structure. When the information for a plot is being accumulated the DISSPLA system goes through a series of four levels. After each successive level is reached it is not possible to return to a lower level until the plot is finished. Therefore, since all information has a specific level or levels that it can be defined on, ASGOL must also ensure that a new level is reached only after all required information has been specified. Table 1 lists these levels and their meaning.

TABLE I

DISSPLA Levels

| Level | Status |
|---|---|
| 0 | Initial Status |
| 1 | After Initialization Routine |
| 2 | Page Dimensions, Axis lengths and Physical Origin Have Been Defined |
| 3 | Step Size Defined. Plot is Fully Determined. |

The DISSPLA system also consists of a number of Post Processors which prepare output for various display devices. Currently available on the CYBER are the following: CALCOMP, Tektronix 4010, Tektronix 4014, ZETA plotter, and CDC274 (Ref 3:2). These processors take the file created by the plotting routines and allow the plots to be seen on a number of devices (Figure 1). In addition the plots can be modified according to the following features:

1. selective plotting,
2. windowing of a plot (blow-up),
3. relocation of plots relative to each other,
4. scaling,

5. superimposing of plots (Ref 3:5).

These features are well defined in the DISSPLA manual and required only minor actions from the ASGOL system to be available.

## System Configuration

The ASGOL system consists of three main parts; the Parser, the Semantic routines, and the Interpreter. The parser performs the syntax checking of ASGOL and when applicable calls the appropriate semantic routine. See Chapter 4 for details of the parser construction. The semantic routines in turn check the semantics of the language and generate the appropriate AIL instructions to perform the required plot functions. These routines are part of the parser and are also discussed in more detail in Chapter 4. Finally, the interpreter is responsible for decoding and executing the AIL instructions and generating the necessary DISSPLA commands. See Chapter 5 for a complete discussion of the structure and function of the interpreter.

By using a file to pass the AIL instructions from the parser to the interpreter the ASGOL system was separated into a two step process. This allows the parser to be run to check syntax without running the interpreter. In the

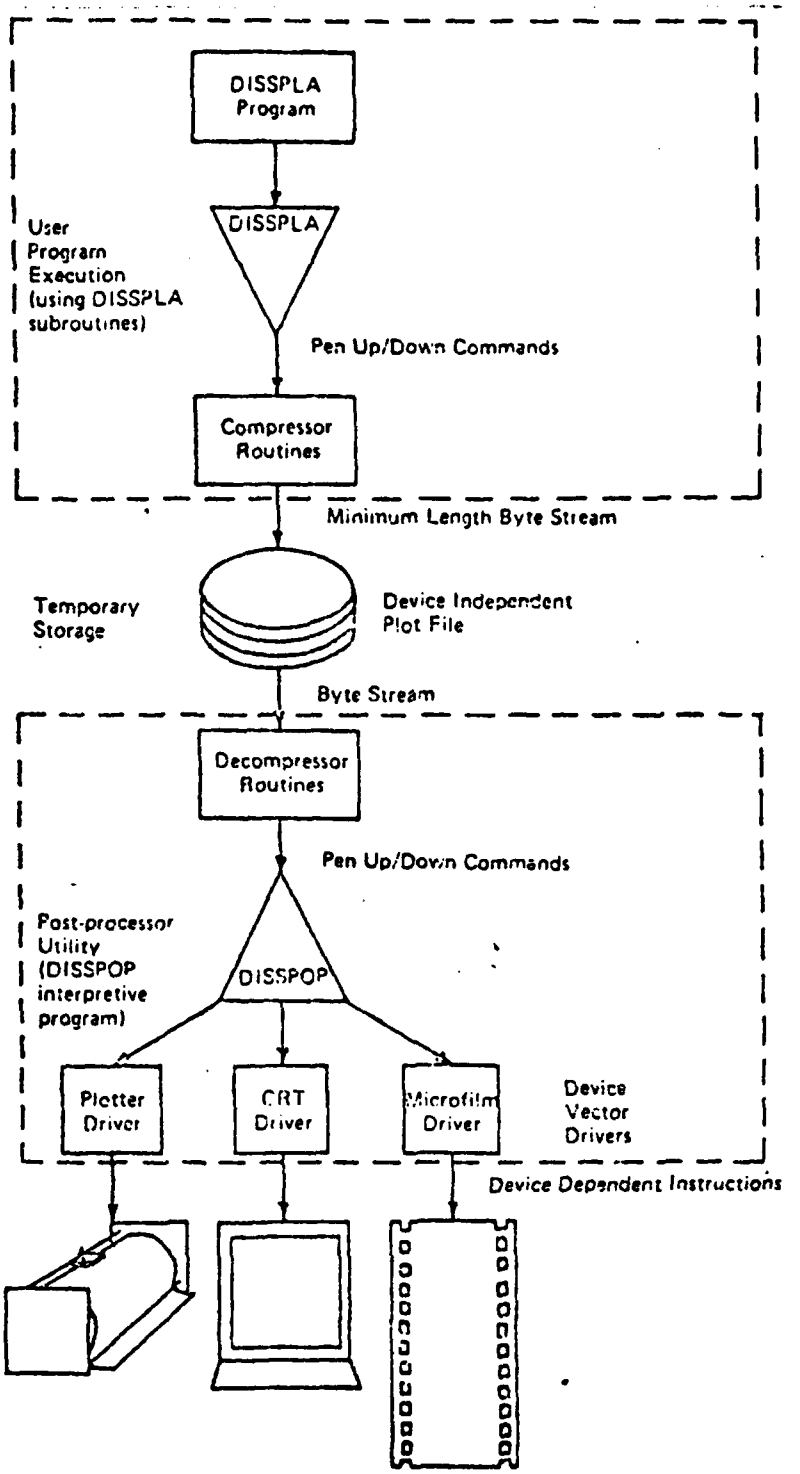



Figure 1. DISSPLA Processing

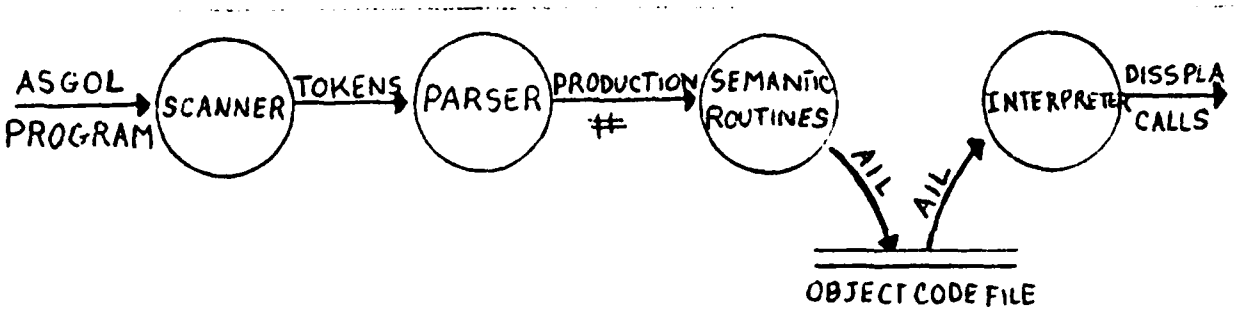



Figure 2. Functional System Chart

same way the interpreter can be run as often as desired without having to rerun the parser portion of the system. Figure 2 shows the relationship of the parts of the ASGOL system.

# III. ASGOL Language Design

## Format

The intention of ASGOL, as designed by Lt. Hart (Ref 1:7-17), was to be as independent of DISSPLA and as machine independent as possible. The first objective was met by assuring that a one-to-one correspondance of ASGOL statements to DISSPLA commands was not forced upon the user. ASGOL instructions were designed to be meaningful English language statements and, so, one statement could generate a sequence of DISSPLA commands or no commands at all. (See Appendix A for a listing of the ASGOL productions.) Although this makes the code generation in the parser more difficult, the advantages to the user are well worth the extra effort as this effectively frees the user from the need to know any details of the DISSPLA system.

By basing the language on ALGOL, a high-level language, the second objective was achieved. A high-level language can be largely machine independent, therefore, it is not necessary to even know what computer the system is to be run on to write the ASGOL program. However, this does not imply that the current implementation can be run on any machine since it contains several CDC dependent routines. It simply means that an ASGOL language contains no machine dependant

features.

For further ease in using the language, ASGOL was also made free format. This means that there is no column dependency (such as in FORTRAN) for the instructions. The user is totally free to space the instructions over one or several lines as necessary for program clarity. There is also no restriction on the number of lines or cards that can be used for this purpose.

```
PROGRAM example
    DECLARE
        CONSTANT PI = 3.14159 /* comment on same line */
        VARIABLE
            A, /* instruction over many lines */
            B, /* with comments within the */
            C, /* instruction.  */
            D : INTEGER
    END DECLARE
END PROGRAM example.
```

Figure 3. Program Layout With Comments

To complement this freedom of spacing, the ability to place comments anywhere within a program, was provided. Comments begin with the characters /* and end with */. Anything in between is ignored by the compiler so comments can appear on the same line as an instruction or even within an instruction. Figure 3 shows examples of line spacing and comments. Note that the spacing can be used for indentation. With these features, the ASGOL program should be easily readable and understandable.

Unlike some other languages that have been designed to interface with DISSPLA (Ref 5), ASGOL was not structured to be open-ended. In an open-ended language it is necessary to specify only the beginning parameters in a list if the remaining are to be used with their default values. This approach works well until it becomes necessary to change only a parameter at the end of the list. In this case the default values, if known, have to be entered or a series of commas must be used to designate the parameters' positions. It is obvious that this can lead to difficulties if a default value is forgotten or if the number of commas is miscounted. To avoid these difficulties, any parameter that is optional in ASGOL will assume a default value if it is not specified. Just removing the parameter from the list is sufficient to acomplish this. For example, in the definition of a page the margin parameter is optional. If included the instruction becomes:

PAGE example (VERTICAL,LEFT RESET,1.0,TOP).

If, however, the default value is all that is needed the instruction simplifies to the following:

PAGE example (VERTICAL,1.0,TOP).

Not only is this easier to deal with, it eliminates the potential for errors present in the other approaches.

## Block Structure

When large programs are written it is commonly agreed that they need to be divided into smaller modules whenever possible. This is true for the following reasons:

1. improved readability;
2. improved testability;
3. enhanced organization (Ref 6:281).

To accomplish this aim, subprograms have been incorporated into most languages. Initially the two types, procedure and function, were allowed to communicate with the main program only through parameters passed by the calling mechanism. This approach was sufficient as long as the desired amount of data to be shared was small. If not, the parameter list could be quite long, thus, creating two bad situations: "first, no one wants to type lists with 15 or 20 members; second, a long list is error prone in that a programmer could easily permute the order of arguments or leave one

out" (Ref 6:298). In an effort to eliminate this problem, FORTRAN allows COMMON blocks to be defined and shared among subprograms. Although the initial problem is solved by this approach others are created. In making the module interfaces more complex, the reliability of the program is decreased and therefore debugging time is increased.

From a software engineering point of view this is not really an acceptable situation. Therefore, a different type of program structure was developed. This is known as block structure and it uses the physical organization of the modules to determine data access rights. Only modules that are physically nested within another module can use the data within that module. This allows the user to set up a program in such a way that any module has access only to the data that it needs (Ref 6:298-299).

As an added advantage, a block structure approach allows some space to be saved at execution time. Since the data for a particular block is only needed while that block is executing, dynamic storage allocation can be used. When a block is activated, storage for its variables is allocated and when execution for that block is complete the storage is returned to be used by the next block. Depending on the program, this could result in a major savings of storage space (Ref 6:300).

```
PROGRAM one
    SECTION one
        PAGE one
            SEGMENT one
            END SEGMENT one
        END PAGE one
    END SECTION one
END PROGRAM one.
```

Figure 4. ASGOL Program Levels

In the origional design of ASGOL it was desired that it be as efficient and easy to use as possible. In addition the amount of storage used by the system was a concern. Therefore, it was decided to use a block structure. Not only was the design of ASGOL programs made simpler through the use of modularity but a savings in storage was also realized. Within an ASGOL program there are four possible levels that can be used. They are PROGRAM, SECTION, PAGE, and SEGMENT and they are the only procedure blocks available. Figure 4 shows the relationship of these levels. See Appendix F for a detailed discussion of their meaning and use.

## Loop and Control Structures

Looping and control statements are an essential part of any language. Because few applications allow a strictly sequential approach, a language is severely restricted without these statements. Therefore, ASGOL was modified to include five looping and control statements.

IF THEN ELSE. This statement can take one of the following two forms:

```
IF expression THEN commands END IF
IF expression THEN commands ELSE commands END IF
```

FOR. The for statement also has two forms and is used to repeat a sequence of instructions a specific number of times.

```
FOR variable = expression TO expression BY expression
    DO commands END FOR
FOR variable = expression DOWN TO expression BY
    expression DO commands END FOR
```

WHILE DO. This statement is used to execute a sequence of instructions as long as a given expression is true.

```
WHILE expression DO commands END WHILE
```

REPEAT UNTIL. This statement is the same as the WHILE DO with the exception that the instructions are executed until the specified expression becomes true.

```
REPEAT commands UNTIL expression END REPEAT
```

CASE. This statement provides a multi-path branching capability for ASGOL. Although the same function could be accomplished using nested IF THEN ELSE statements, the CASE statement was provided for clarity.

```
CASE variable OF
     list : commands
     list : commands
     OTHERS : commands
END CASE
```

See Chapter 4 for a discussion of how these statements are handled by the semantic routines and Appendix F for rules concerning their use.

# IV. Parser

## Scanner

The first step in any compiler or interpreter system is to reduce the input language string to a form that is more easily used by the computer. It is both wasteful and unnecessary to deal with a character string such as "DECLARE" when an integer value would work just as well. The integer could convey the same meaning and also save space while simplifying processing. This is just one of the functions of the scanner.

Since the input STREAM is treated as one continuous character string, the scanner must perform all the following functions:

1. Identify reserved words, PROGRAM, DECLARE, FRAME, etc;
2. Identify special symbols, =, <, >, etc;
3. Identify and convert numeric constants, 10, 27.4, 131, etc;
4. Identify and collect character constants, "ABC", "X123", etc;
5. Identify and collect identifiers.

ASGOL's scanner performs all of these functions and conveys the results to the rest of the system through its calling parameter, ITOK, and several associated variables, RVAL, IVAL, SYMSTR, STRING, and SLNGTH. For reserved words

and special symbols ITOK's value is an index into the vocabulary array. No other information is required for processing of this type of information since it is usually only necessary to know that the reserved word or special symbol is present. The remaining three functions, however, require more information to be meaningful.

When a numeric constant is encountered, ITOK, is set to a predefined value and the constant is converted to machine format. It is then placed into one of two variables; IVAL, if it is an integer, or RVAL, if it is real. These variables are in the COMMON block LEXCOM so they are thus available to the rest of the system. Character constants are handled in a similar manner with a predefined value being assigned to ITOK. No conversion is performed though. Instead the characters are placed one character at a time, as they are read, into the array STRING. When the end of the string is detected, STRING contains the entire character string with one character stored per word. The string's length is then put into the variable SLNGTH. STRING and SLNGTH can also be found in the COMMON block LEXCOM. If the scanner cannot identify a character string as either a reserved word or a special symbol, it assumes the string is an identifier. In this case the string is put into the array SYMSTR, also found in LEXCOM, and ITOK is set to the predefined identifier value.

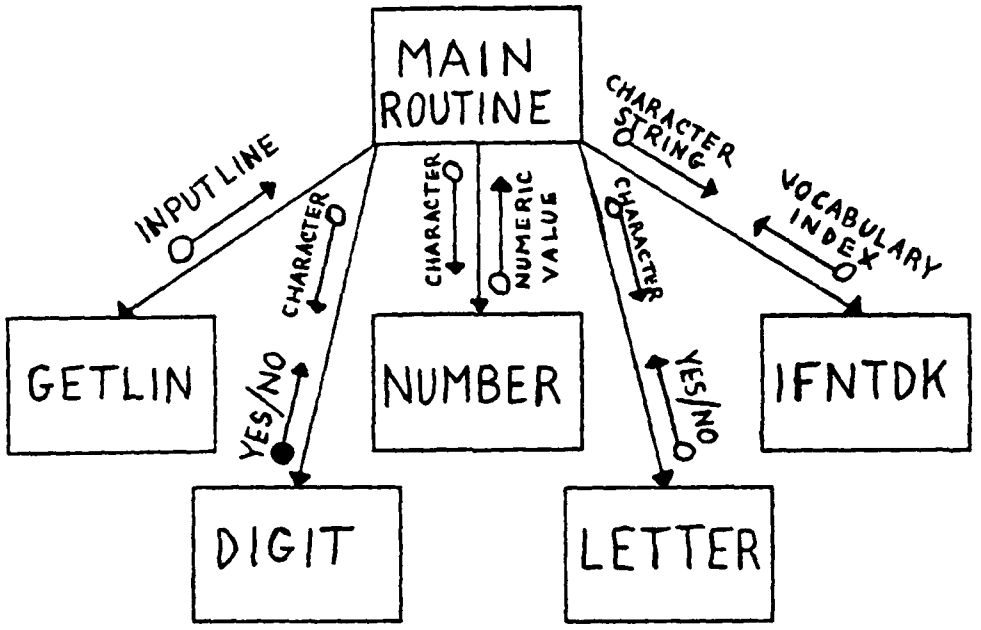



Figure 5. Scanner Organization

Construction. Figure 5 shows the relationships between the various scanner routines. They consist of the main routine, the input routine GETLIN, the conversion routine NUMBER, and the identification routines IFNDTK, DIGIT, and LETTER. See Appendix E for more information on the specific functions of each of these routines.

## Parser

LR(1). During the design of ASGOL, the decision was made to use an LR parsing approach. Although the major motivation was probably the ability to utilize the Automatic Parser Generator obtained from Lawrence Livermore Laboratory (Ref 7), there are many other advantages to this technique. When compared to an LL parsing approach it has been shown that LR parsing is not only more powerful (any LL(K) grammar is also LR(K)) but there are available commercially proven tools to construct LR parsers from a given grammar (Ref 8:157). In addition LL parsing is a top down recursive technique and since the ASGOL system was forced to be written in FORTRAN IV, which does not easily support recursion, LL parsing was not practical.

The LR parsing technique is a left-to-right, bottom-up approach. It starts with an input string and then reduces it to a goal symbol (Ref 8:158). This is accomplished by performing the steps in Figure 6. When neither a reduction nor a transition is possible a syntatic error has been detected, meaning that the rules of the grammar have not been followed correctly. At this point parsing cannot continue unless some kind of error recovery is performed. Unfortunately error recovery for a table driven parser is a difficult process. Therefore little was done within the scope of this thesis to find a solution to this problem.

```
STEP1:  GET TOKEN FROM SCANNER
STEP2:  IF REDUCTION POSSIBLE
        PERFORM REDUCTION
        GO TO STEP1
STEP3:  IF TRANSITION POSSIBLE
        PERFORM TRANSITION
        GO TO STEP1
```

Figure 6. LR Parsing Steps

See Chapter 7 for a further discussion of this problem.

Automatic Parser Generator. The basis of the parser used in the ASGOL system is a series of tables produced by an automatic parser generator obtained from the Lawrence Livermore Laboratory (Ref 7). This program takes a contex free grammar expressed in a modified BNF format and generates tables that describe an LR(1) parsing automaton. These tables are then incorporated into the parser and are all that is required to verify the syntax of the language. This approach is particularily useful if any changes are made to the language since they can be included simply by generating new tables (Ref 7:1).

This, however, does not mean that a language can be expanded indefinitely. As a language grows the size of the table output also grows because the table output is roughly linearly proportional to the number of states in the automaton. These states are generated at a rate of about one for every right hand side symbol in the BNF. Since the average production length of most languages seems to be about two symbols, the parser will have roughly twice as many states as productions (Ref 7:7). When space is a concern, as it was with the ASGOL system, this can have a limiting effect on the size of the language.

In addition to this concern there is a problem with this table approach that is not discussed in the Automatic Generator documentation but needs to be mentioned. As long as syntax checking is all that is required this system works well. However, ASGOL, as well as other languages, also needs to have semantic checking and code generation done. The parser is set up to do this by passing the production number of the reductions that are being performed to a set of semantic routines. These routines can then do any required validation and code generation. As long as no changes are made to the language there is no problem, but when a change is made and new tables generated the production numbers may change. Since the production number is the key to the semantic routines a way of correlating the numbers to their appropriate routines is necessary. This

can be done two ways. First, if the language is small enough the routines can be shifted as the numbers change. However, as the number of productions increases this approach can result in a great deal of work and a potential for mistakes when the shifting is done. The second way to solve this problem is to create a cross reference table that keeps track of the routines' location. When new tables are then generated this table is all that needs to be changed. The ASGOL parser uses this approach through the table XREF. Appendix A shows the relationship of the productions and their respective semantic routines for the BNF of ASGOL.

Construction. The parser consists of several routines that determine reductions, transitions, and semantics. Figure 7 shows the relationship of these routines. See Appendix 4 for a detailed description of each.

## Semantic Routines

It is not enough just to know that a program is syntactically correct. When variables are used in a program it is usually necessary to know more than just their names. Other information, such as type, dimension, etc., is also needed if the data referred to by that variable is to be processed correctly. It is one of the functions of the

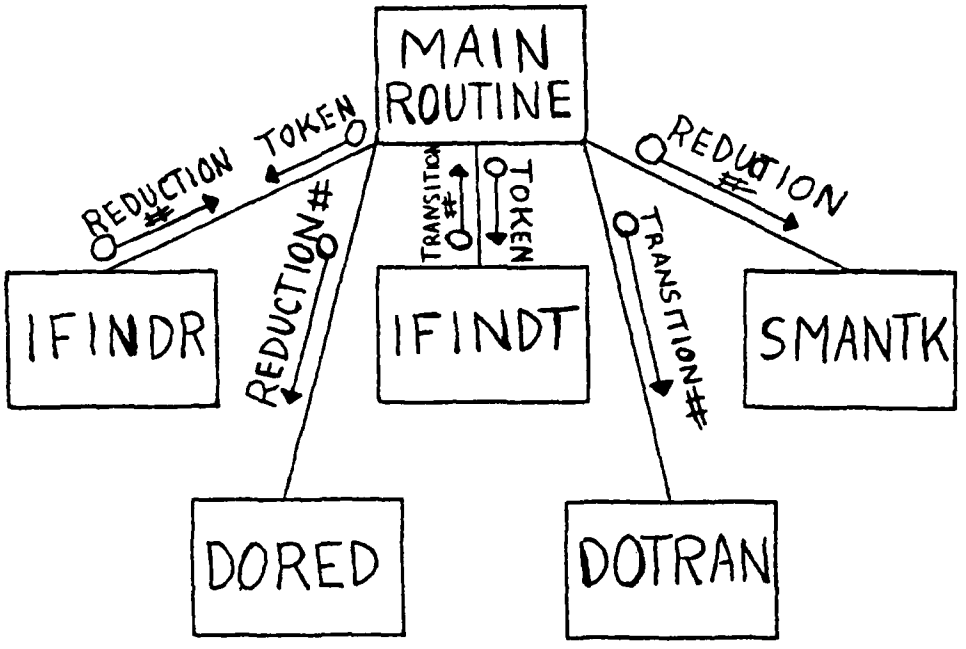



Figure 7. Parser Organization

semantic routines to keep track of this information and to insure that all references to variables are consistent with it.

The other main function of the ASGOL semantic routines is to generate AIL instructions. These are instructions to the interpreter and will be discussed in detail in Chapter 5.

Symbol Table. The symbol table is made up of 9 arrays, BSCTYPE, LEXLEV, POINT, ARRAY, DEFINED, MODE, ENTRYPT, NEXTENT, and NAME. By storing in these arrays information about each variable used in the program, the semantic routines are able to verify that a variable is being used correctly. However, since most programming languages, ASGOL included, have an extremely large set of possible identifier names, (FORTRAN contains approximately 1.62x10**9), it is not possible to have one entry in these arrays for each possible identifier (Ref 9:111). Instead only variables that have been used in the program are put into the symbol table. This solution does decrease the amount of storage space required but it also leaves the problem of searching the table for desired identifiers. Of the many different organizational and searching techniques(Ref 9, Ref 10), a hashing approach was chosen for the ASGOL system.

"A hashing function partitions the set of all source codes into equivalence classes such that two source codes are in the same equivalence class if and only if they have the same bit pattern" (Ref 10:114). This is a strict definition of a hashing function and simply means that the function operates on an identifier to obtain a value. The value is then used as an index into the symbol table. The array ENTRYPT is used for this purpose as shown in Figure 8. The value obtained from evaluating in sequence the following three hash functions is used as a pointer into the array

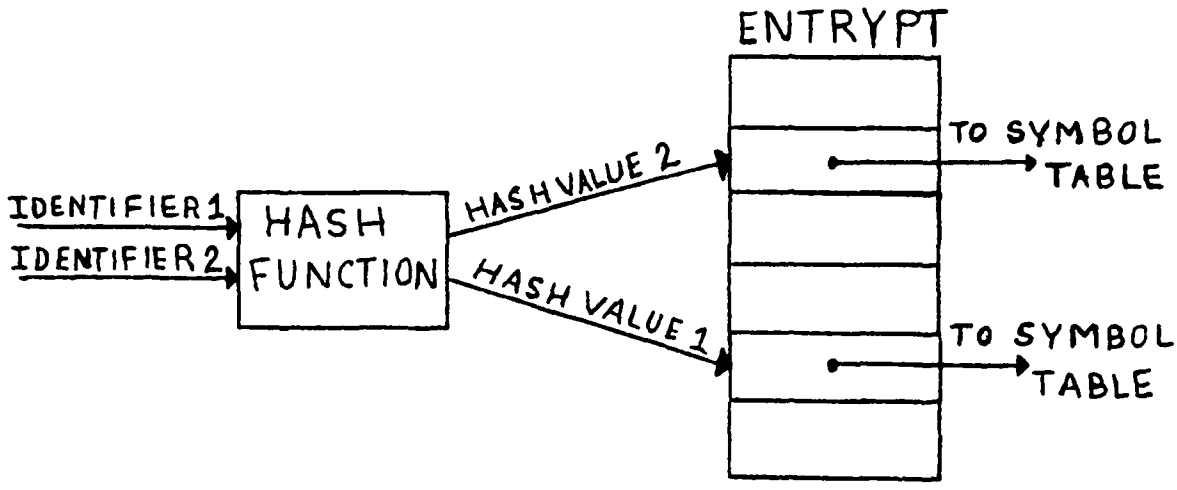


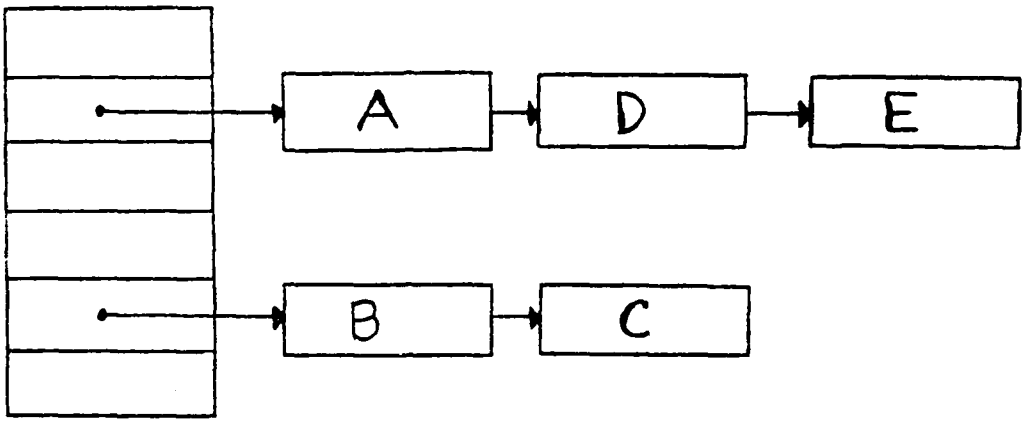

Figure 8. Hash Function Example

ENTRYPT which then contains a pointer into the other symbol table arrays.

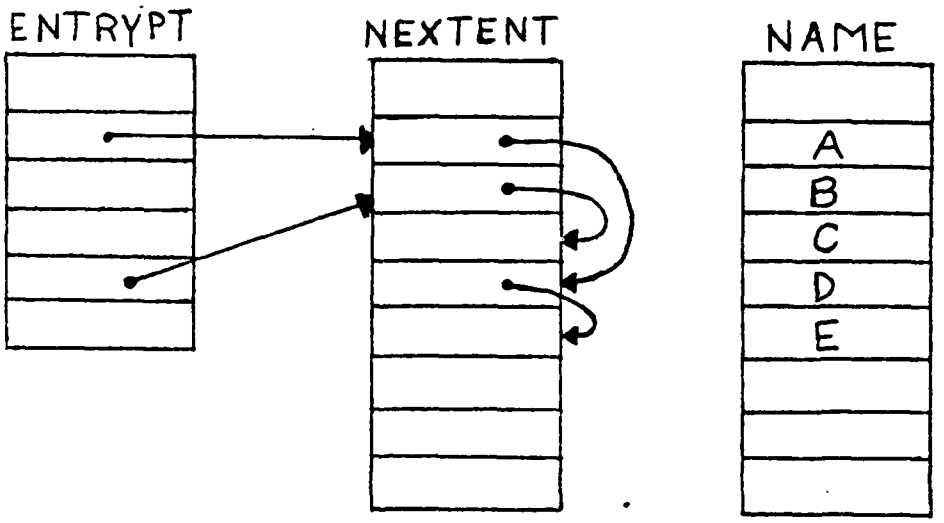
```
value = sym(1) + 3*sym(2) + 5*sym(3) + 7*sym(4) +
        11*sym(5) + 13*sym(6) + 17*sym(7) +
        19*sym(8)
value = int(value * 160795.0/262144.0 * 50 + 0.5)
value = mod(value,50) + 1
```

With the large number of identifiers possible and the limited number of entries in ENTRYPT, 50, it is clear that not all of the values can be unique. In other words two identifiers may yield the same value. This is called a collision and can be handled in several ways. The ASGOL system uses the array NEXTENT to help resolve these conflicts. With this array all identifiers that result in the same value are put into a chain as shown in Figure 9. Since all the arrays, except ENTRYPT, of the symbol table are parallel the information for any variable in the chain can be obtained simply by using the current index of the NEXTENT array.

Because of space limitations it was necessary to restrict the symbol table to only 100 identifiers. Although this does not seem to be enough for a large program, it is sufficient if the block structure of ASGOL is utilized. By only keeping identifiers that are part of active blocks the same space in the table can be used again and again. This, however, presents the problem of identification of the variables to be removed from the table when a block ends. The array LEXLEV is used for this purpose. As each new block is entered the lexical level of the system is increased and this value is placed into the symbol table for every variable defined in that block. In addition as each variable is added to the table it is put at the head of a hash chain. Since identical variable names can be used in




(A). Hash Chains




(B). Hash Chain Implementation

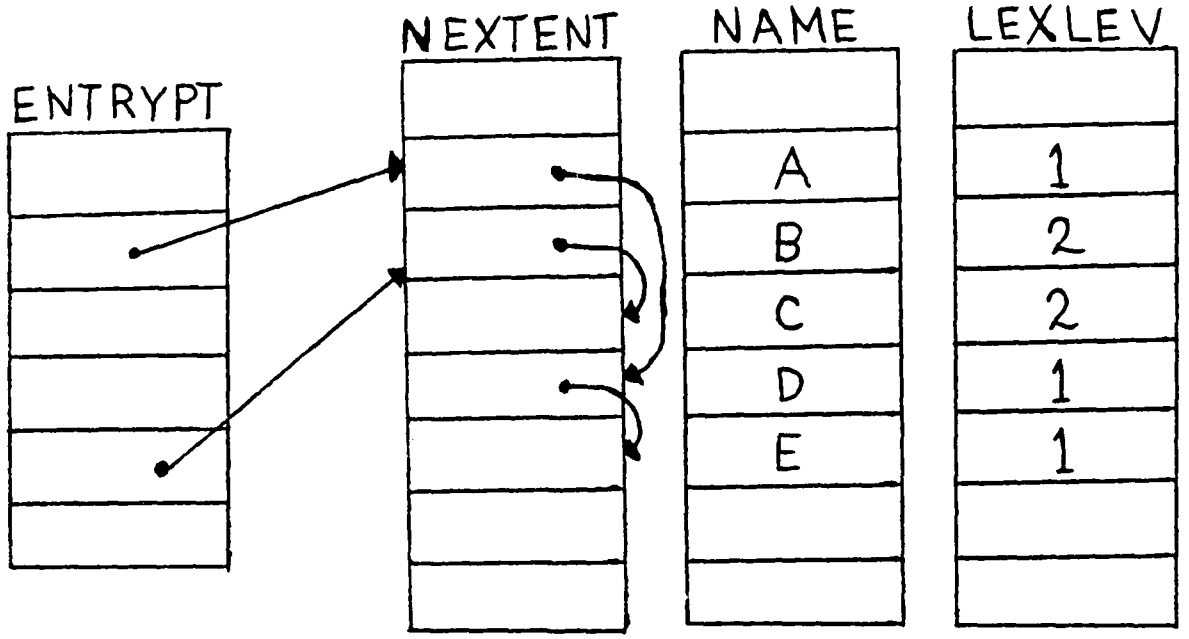
Figure 9. Hash Chaining

different this also assures the latest definition will always be the one used. This also makes deallocation of the variables easier. When a block is exited all the variables in the table that have the same lexical number as the block are removed. To do this each chain is searched to the end or until a lower lexical number is found. Clearly not all of the table has to be searched resulting in faster execution. Figure 10 shows how this has been implemented.

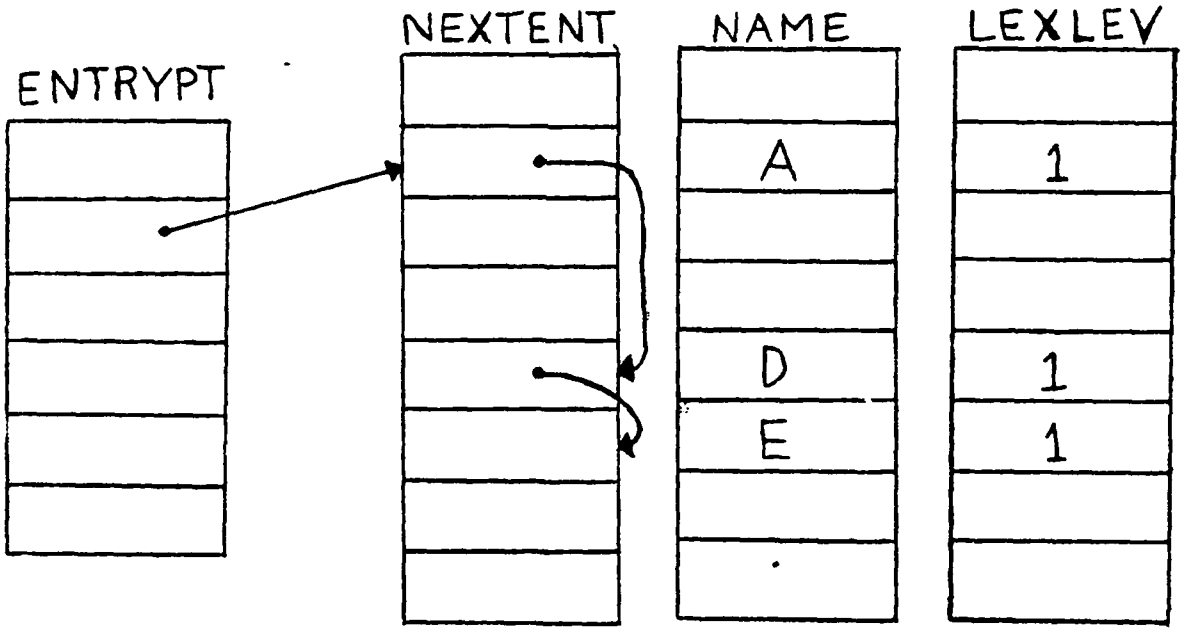
Implementation of Labels. When looking at the productions for the conditional and looping statments, Appendix C, the primary confusion is likely to be the handling of labels in the intermediate language. Since some labels must be referenced before they are defined it is not always readily apparent what is happening during code generation.

To resolve labels the ASGOL system uses a stack and two tables, BRSTACK, and LABSTK. Whenever a label is needed a special routine, GETLAB, is called to generate a unique label number. This number is then used for all subsequent references to that label.

If the label is being referenced by a jump instruction then the label number and the address in the instruction stack of the AIL instruction are put into the BRSTACK table. This information is thus held until the label is defined. At this point two things happen. First the location of the




(A). During Execution of Level 2




(A). After Termination of Level 2

Figure 10. Lexical Level Termination

label in the instruction stack and the label number are saved in the table LABSTK. Then the BRSTACK table is searched and any references to that label are resolved by the following formula:

ADDRESS = ADDRESS OF LABEL - ADDRESS OF REFERENCE

It is clear that this formula generates an address relative to the point where the label is referenced. The advantage here is that the instructions are not restricted to any particular location in the interpreter. Not only are modifications made easier this way but larger programs can be run a segment at a time.

In addition to the tables mentioned, labels may be stored temporarily on a stack if an instruction is using more than one label at any particular time. This is strictly temporary to allow the reductions to keep track of the labels being used.

Finally, when a label is no longer needed it is removed from the LABSTK table and all remaining references in the BRSTACK table are also removed. Since all labels are generated and used within the system, transparent to the user, there is no difficulty in knowing when a label is no longer needed. Therefore the possibility of unresolved or unreferenced labels does not exist.

# V. Intermediate Language and Interpreter

## AIL

Because execution was delayed to allow for the looping and control structures, a way of saving the program instructions was required. The ASGOL Intermediate Language(AIL), see Appendix B, was designed for this purpose. These instructions are created by the parser (semantic routines) and are subsequently executed by the interpreter to generate DISSPLA calls. Although an intermediate language approach can result in decreased running speed of the program, it can also have advantages that offset any losses if it is designed correctly (Ref 11:10). In addition, in the ASGOL system, it allows for the breakup of the processing into two parts. AIL can be stored on a file by the parser and executed by the interpreter as often as desired.

An intermediate language(IL) usually consists of a few simple operations that are semantically equivalent to the original program (Ref 12:466). ILs are not designed to be used by people, but instead are entirely internal to the system and are usually unknown to the user (Ref 11:10). This is true with AIL as the user will probably never see these instructions. ILs can take several forms including:

1. Quadruples,
2. Triples,
3. Postfix, and
4. Infix (Ref 12:466).

A quadruple is a 4-tuple consisting of an operation code, two operands, and a result destination. For example, the expression A = B * C would be represented by the sequence:

*,B,C,A.

A triple is essentially the same as a quadruple, except that the result destination is implied by the location of the instruction (Ref 12:467). For example, A + B * C would be represented by

(1) *,B,C
(2) +,A,(1).

The (1) in expression (2) refers to the result generated by expression (1).

Both the infix and postfix notations, also known as Polish and Reverse Polish respectively after the Polish logician J. Lukasiewicz who first employed them (Ref 13:162), are continuous strings where each operation refers to either the two preceeding or two following operands. This type of representation is convenient for arithmetic expressions because parenthesis are not needed. However, it is very cumbersome when optimization and other functions are desired (Ref 12:470).

AIL does not strictly follow any of these notations. Instead it employs a variable format that ranges from just an operation code, CONT, to a 5-tuple, GRAPH,T,F,S,I. It is based on AOC (ALGOL Object Code) as presented by Barrett and Couch (Ref 12:376-463). AOC essentially forms the basis of AIL with instructions added to AOC to provide the graphic capabilities needed for ASGOL. AOC was chosen for this purpose because it can support essentially all of the features of ALGOL 60 (Ref 12:377) upon which ASGOL was based. In addition it provides the variable instruction format. By employing a stack as either an operand or a result destination the amount of information required in any one instruction was reduced. The main advantage to this approach is that less space is required for the instructions than if a straight 5-tuple was used. More processing time is required but the wasted space of the 5-tuple approach is avoided.

Interpreter

A compiler that generates target machine code directly, instead of an intermediate language, is usually more efficient and produces more effecient code (Ref 12:473). To take advantage of this situation, AIL was designed around a machine that was based on the AOC machine shown in Barrett

and Couch (Ref 12:377-463). This machine contains two stacks, a display for each stack, two stack pointers, a display pointer, an instruction area, and an instruction pointer as shown in Figure 11.

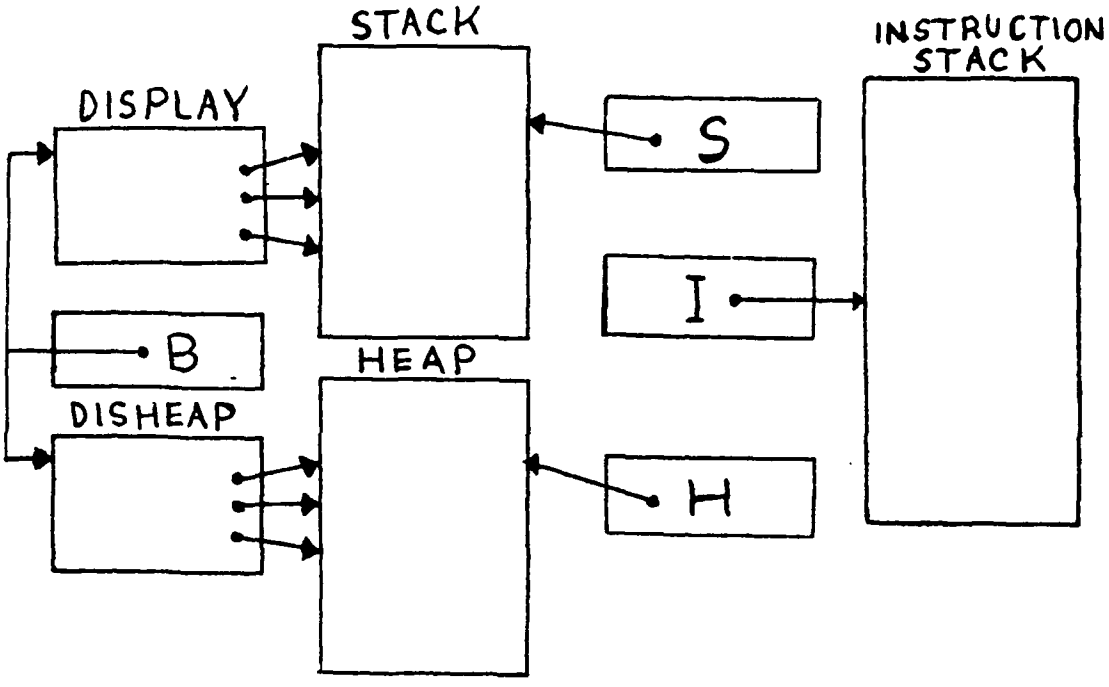



Figure 11. Interpreter Machine Structure

The area STACK is used to store data and intermediate results. Virtually all of the implied operands and result locations are in this area. The only exceptions to this

statement occur when character strings or array data are being used.

ASGOL allows dynamic dimensioning of arrays and strings. This means that the compiler does not know what the dimensions are going to be. Therefore at compile time it can only set up pointers and cannot reserve any space. The needed space is allocated at execution time and is always found in the stack HEAP. This is the sole function and purpose for this area.

To keep track of the block levels in each stack a display area is used for each. They are DISPLAY and DISHEAP and are used as shown in Figure 12.

Each area is an array of pointers to the beginning of each block. They serve two major functions. First they provide relatively quick access to the data defined at each level and second, they allow for quick, easy deallocation of blocks.

The other major area of the machine is the instruction stack. The AIL instructions are read into this area initially. The interpreter then starts a sequential execution of the instructions. As each is decoded the interpreter performs any manipulations required and generates DISSPLA calls when appropriate. This process continues until all of the instructions have been processed and the job is complete.

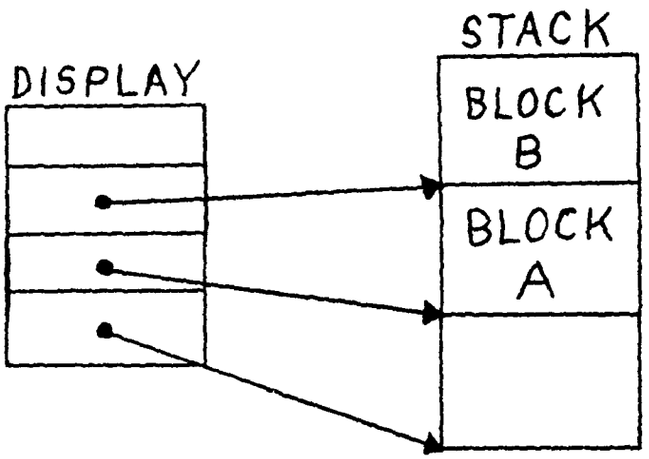



Figure 12. Use of Display Areas

# VI. Applications

It is the purpose of this chapter to show examples of ASGOL code and the resulting plots for many of the applications of this system. They are taken from the examples presented by Lt. Hart (Ref 1). Only the major applications will be demonstrated, however, and no attempt is made to explain them here. For detailed explanations refer to the user's manual found in Appendix F.

```
   .
   .
   .
PAGE example_4(HORIZONTAL,CENTER, . . .
  MARGIN(1.25 INCHES,0 INCH)
  DRAW LINE(0 INCH,3.25 INCH,3.25 INCH,0 INCH)
  DRAW LINE(3.25 INCH,0 INCH,6.5 INCH,3.25 INCH)
  DRAW ARROW 01(3.25 INCH,3.25 INCH,
                  0 INCH,6.5 INCH)
  DRAW ARROW 32(0 INCH, 6.5 INCH,
                6.5 INCH,6.5 INCH)
  DRAW LINE(6.5 INCH,3.25 INCH,3.25 INCH,6.5 INCH)
  DRAW ARROW 03(0 INCH,0 INCH,3.25 INCH,6.5 INCH)
  DRAW LINE(3.25 INCH,6.5 INCH,0 INCH,3.25 INCH
END PAGE example_4
   .
   .
   .
```

Figure 13. Line and Arrow Instructions

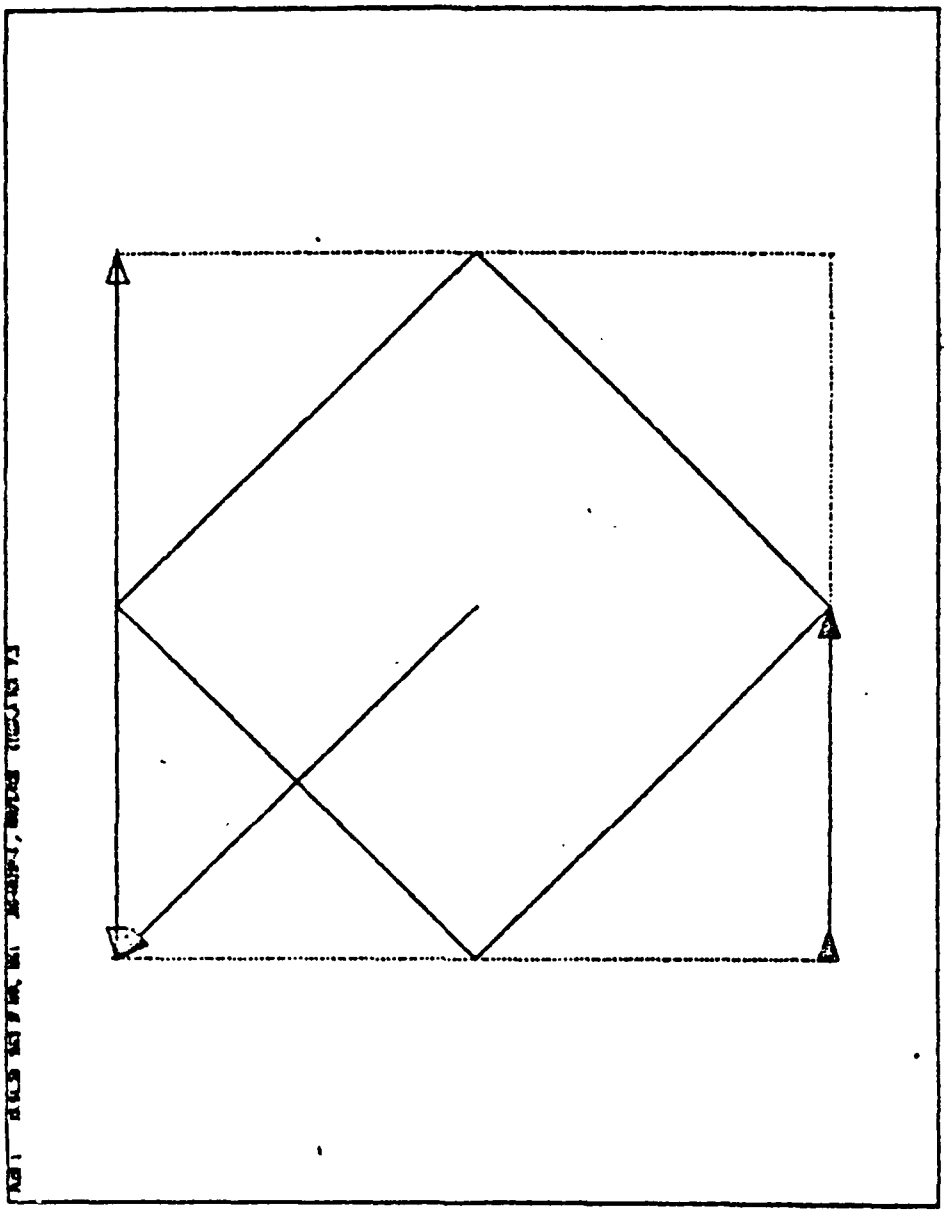


Figure 14. Line and Arrow Plot

```
PROGRAM exampleb_1
  PAGE drawb_1(HORIZONTAL,LEFT RESET,0,TOP)
    SEGMENT draw_bar(0 INCH, 4.25 INCH,     /* x dimen */
                     0 INCH, 6.5 INCH)      /* y dimen */
    FRAME    /* enclose plot */
  /* scaling of axes within the subplot area
        will occur automatically */
    X AXIS =("hours",        /* hours of the day */
             0,24,           /* min and max */
                5,           /* # of plots */
                0)           /* no ticks */
    Y AXIS =("decibels",  /* noise level *
                0,120,       /* 0-120 Db */
                  7,         /* every 20 Db */
                  0)         /* no ticks */
    LEGEND "freeway"        /* title legend */
            (LEFT TOP,     /* location */
            "weekdays",
            "weekends",
            "average")       /* note order */
    GRAPH(BAR,3,
        DATA/10,70,56,87,10, /* weekdays */
              6,37,43,40,9,  /* weekends */
              36.8:5/)       /* average */
    END SEGMENT draw_bar
    SEGMENT draw_lin
             (4.25 INCH,8.5 INCH,   /* x dimen */
                0 INCH,6.5 INCH)  /* y dimen */
    X AXIS =("hours",0,24,5,5)
    Y AXIS =("decibels",0,120,7,1)
    GRAPH "noise level"(LINEAR,3,
                   DATA /10,70,56,87,10,
                          6,37,43,40,9,
                           36.8:5 /)
    END SEGMENT draw_lin
  END PAGE drawb_1
END PROGRAM exampleb_1.
```

Figure 15. Bar and Linear Text

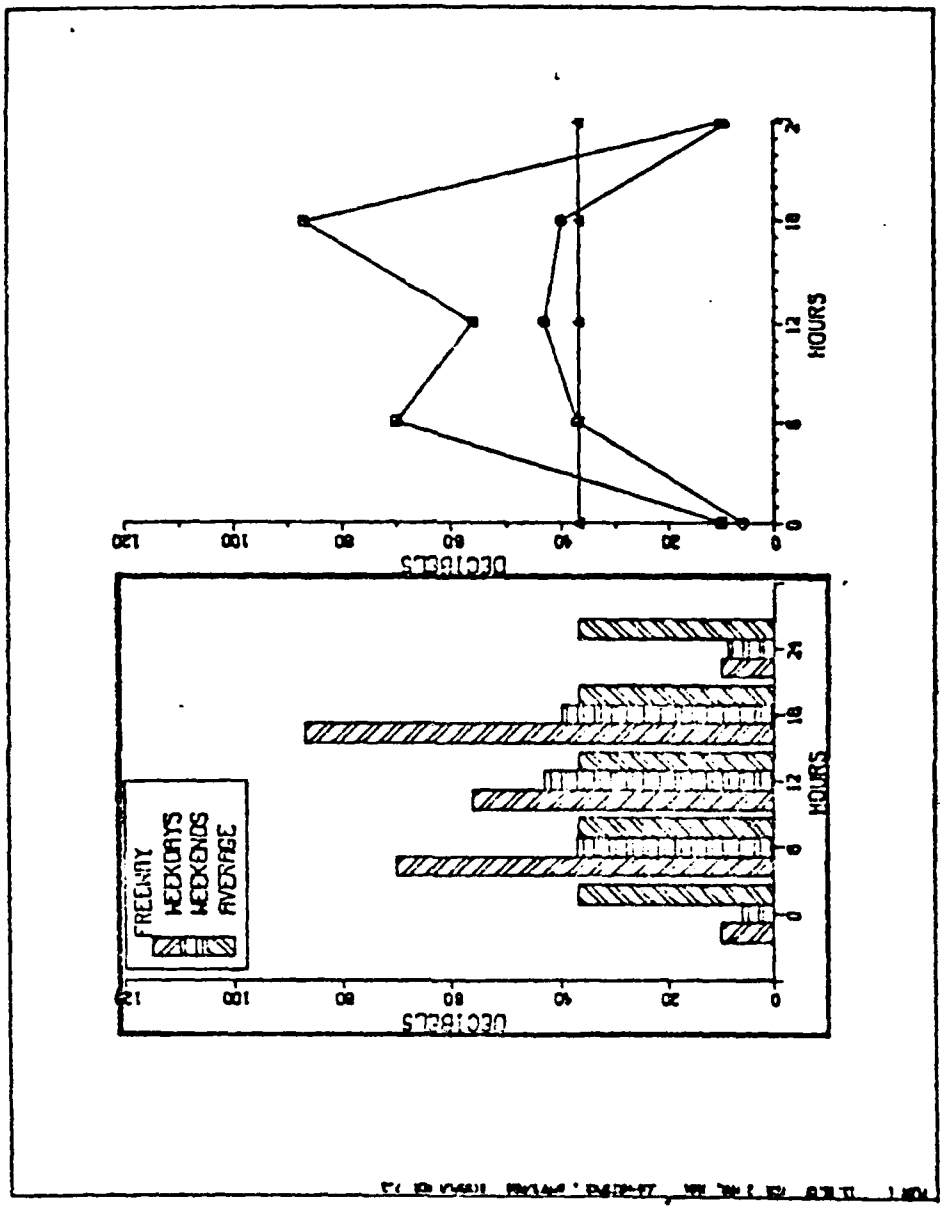



Figure 16. Bar and Linear Graph

```
PROGRAM examplepie
  PAGE drawpie(VERTICAL,CENTER,5,RIGHT TOP)
  MARGIN(1 INCH,1 INCH)
  FRAME
  LEGEND ("cars",          /* automobiles */
          "trucks",        /* 2 and 4 wheel */
          "vans")          /* customized */
  GRAPH "automobile sales"
            (PIE,          /* define pie graph */
               3,          /* # of sections */
             DATA / 47.6,   /* car sales */
                    32.4,   /* truck sales */
                     15/)   /* van sales */
  END PAGE drawpie
END PROGRAM examplepie.
```

FIGURE 31 Pie Graph Example

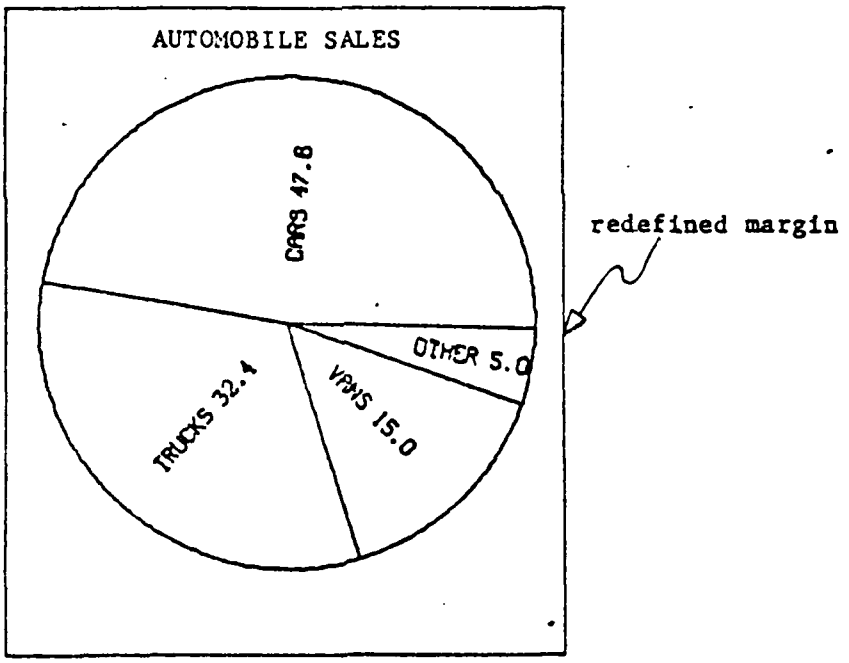



Figure 17. Pie Graph Example

```
    .
    .
    .
PAGE text_examp(VERTICAL,center,0,top)
  SEGMENT l_just(0.00 INCH,4.50 INCH,
                 3.25 INCH,9.00 INCH)
    FRAME
    TEXT(LEFT JUSTIFIED SIMPLE,
         "this is#nlan example#nl"&
         "of justified#nltext",
         1,CONTINUE,.50 INCHES)
  END SEGMENT l_just
  SEGMENT r_just(3.25 INCH,4.5 INCH,
                 6.50 INCH,9.00 INCH)
    FRAME
    TEXT(RIGHT JUSTIFIED SIMPLE,
         "this is#nlan example#nl"&
         "of justified#nl text",
         1,CONTINUE,.50 INCHES)
  END SEGMENT r_just
  SEGMENT t_cent(0.00 INCH,0.00 INCH,
                 3.25 INCH,4.5 INCH)
    FRAME
    TEXT(TOP CENTERED SIMPLE,
         "top#npcentered",
         1,100,.25 INCHES)
  END SEGMENT t_cent
  SEGMENT cent(3.25 INCH,0.00 INCH,
               6.50 INCH,4.50 INCH)
    FRAME
    TEXT(CENTERED SIMPLE,
         "this part not printed."&
         "centered#nltext",
         23,17,.25 INCHES)
  END SEGMENT cent
END PAGE text_examp
    .
    .
    .
```

Figure 18. Text Instructions

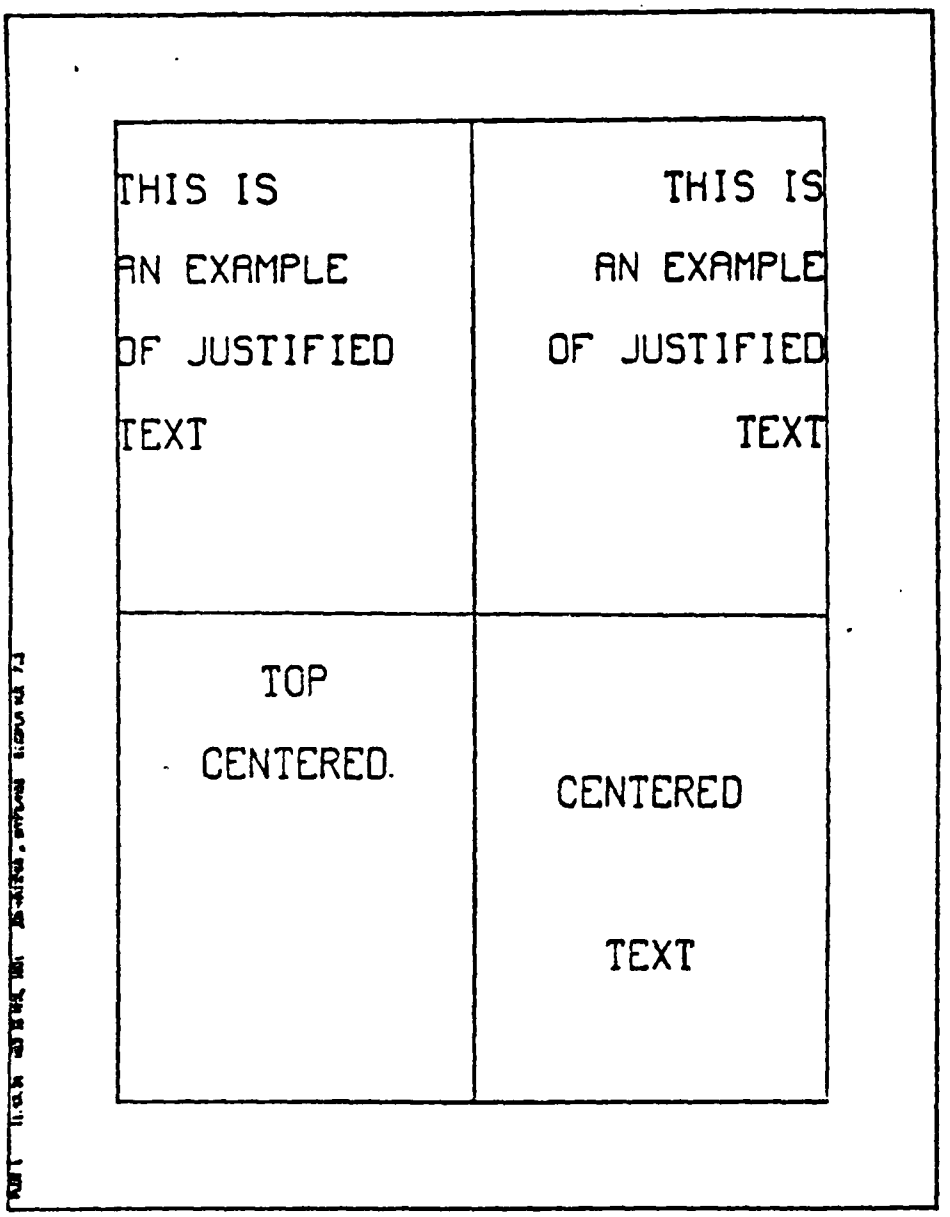



Figure 19. Text Graph

## VII. Recomendations

There are five major areas that are not part of the ASGOL system that could be useful. Therefore they deserve to be explored in more detail. However, this exploration was beyond the scope of this thesis and alone could provide sufficient material for a thesis. These areas are:

(1). Segmentation,

(2). Error Recovery,

(3). Optimization of AIL,

(4). Procedures and Functions, and

(5). Utilization of DISSPLA.

It is important to note that these areas are not listed in order of importance.

### Segmentation

Of the five areas this is probably the most critical at this point. One of the original requirements of the system was that it be designed to run under INTERCOM on the CYBER in a memory space of approximately 65K words(octal). Presently neither part of the system, the compiler or the interpreter with the DISSPLA routines, will run in less than 100K.

There are two approaches to the solution of this problem, overlays and segmentation. Segmentation is recommended because none of the segmentation directives are included in the text of the program. Rather, they are input to the LOADER. This provides a great deal more flexibility to the system. The problem of segmenting the DISSPLA package is currently being worked on so this should be available to anyone who would be expanding ASGOL. Although the compiler has not been segmented, a modular design, with as little interaction between the modules as possible, was used. This approach should allow segmentation with little difficulty.

## Error Recovery

For a compiler to be useful it should not terminate after finding only one error. It would be most beneficial if it would find as many errors as possible during one run. This not only saves programmer time but it also saves computer time making debugging easier and quicker. This is generally a difficult problem. It is particularly difficult with table driver parsers like the one used in the ASGOL system. With the large amount of research that has been done in this area, it is easy to envision this problem solution as a follow-on thesis effort.

## Optimization of AIL

When space is a problem, as in the ASGOL system, the time required to optimize the AIL code could be well spent. By removing redundant code, redundant labels, and code from within loops for example, not only space but execution time can be saved. Like error recovery there is much theoretical material available in this area.

## Functions and Procedures

Functions and procedures are very useful structures in a programming language. They allow code to be executed a number of times, using different data each time, without the need for multiple copies of the instructions. Most of the features of the machine that are required to support these structures already exist in the ASGOL system. Therefore their inclusion in ASGOL is primarily a matter of determining the scope of the routines (a PAGE procedure could not be called from a SEGMENT level plot for example) and changing the BNF to include them. In addition this change would require the modification and addition of semantic routines to generate the appropriate AIL code.

## Use of Additional DISSPLA Features

Many of the features of DISSPLA have been included in ASGOL, but by no means all. As use of ASGOL increases it is reasonable to expect that many of the other features will be desired. It is not difficult to imagine, then, that a follow-on to this thesis could invariably involve the addition of many of these DISSPLA features to the ASGOL system.

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## Appendix A

BNF of ASGOL

This appendix is designed to serve two functions. First it is a formal definition of the ASGOL language. It also functions, however, as a cross reference between the ASGOL productions and the semantic routines. For each production two numbers are included. The first is the production number and the second is the address for the semantic routine in the semantic program.

1
<SYSTEM GOAL SYMBOL> ::= END <PROGRAM> END

2 100
<PROGRAM> ::= <PROGRAM HEAD> <PROGRAM BODY> <PROGRAM END> .

3 200
<PROGRAM HEAD> ::= PROGRAM <IDENTIFIER>

4 400
<PROGRAM BODY> ::= <DECLARATION LIST> <SECTION BLOCK LIST>

5 500
<PROGRAM END> ::= END PROGRAM <IDENTIFIER>

6 600
<DECLARATION LIST> ::= <NULL>

```
7       700
                DECLARE <CONSTANT DECLARATION PART> <VARIABLE
DECLARATION PART> END DECLARE


8       800
<CONSTANT DECLARATION PART> ::= CONSTANT <CONSTANT
DECLARATION LIST>


9        900
                <NULL>


10      1000
<CONSTANT DECLARATION LIST> ::= <CONSTANT DECLARATION>


11      1100
                <CONSTANT DECLARATION LIST> <CONSTANT
DECLARATION>


12      1200
<CONSTANT DECLARATION> ::= <IDENTIFIER> = <CONSTANT
EXPRESSION>


13      33500
<CONSTANT EXPRESSION> ::= <INTEGER CONSTANT>


14      33600
                <REAL CONSTANT>


15      33700
                TRUE


16      33800
                FALSE


17      33900
                <CHARACTER STRING>


18      1300
<VARIABLE DECLARATION PART> ::= <NULL>
```

```
19      1400
                VARIABLE <VARIABLE DECLARATION LIST>

20      1500
<VARIABLE DECLARATION LIST> ::= <VARIABLE DECLARATION>

21      1600
                <VARIABLE DECLARATION LIST> <VARIABLE
DECLARATION>

22      1700
<VARIABLE DECLARATION> ::= <IDENTIFIER LIST> : <TYPE>

23      1800
<IDENTIFIER LIST> ::= <IDENTIFIER>

24      1900
                <IDENTIFIER LIST> , <IDENTIFIER>

25      2000
<TYPE> ::= <BASIC TYPE>

26      2100
                <ARRAY TYPE>

27      2200
                STRING ( <EXPRESSION> )

28      2300
                AXIS

29      2400
                UNIT

30      2600
<ARRAY TYPE> ::= ARRAY <BOUNDS> OF <BASIC TYPE>
```

```
31      2700
<BOUNDS> ::= ( <ARRAY BOUNDS> )


32      2800
<ARRAY BOUNDS> ::= <EXPRESSION>


33      2900
                <ARRAY BOUNDS> , <EXPRESSION>


34      3000
<BASIC TYPE> ::= INTEGER


35      3100
                REAL


36      3200
                BOOLEAN


37      3300
                CHARACTER


38      3400
<SECTION BLOCK LIST> ::= <SECTION LISTING>


39      3500
                <PAGE LISTING>


40      3600
<SECTION LISTING> ::= <SECTION>


41      3700
                <SECTION LISTING> <SECTION>


42      3800
<SECTION> ::= <SECTION HEAD> <SECTION BODY> <SECTION END>


43      3900
<SECTION HEAD> ::= SECTION <IDENTIFIER>
```

```
44      4100
<SECTION BODY> ::= <DECLARATION LIST> <PAGE LISTING>


45      4200
<SECTION END> ::= END SECTION <IDENTIFIER>


46      4300
<PAGE LISTING> ::= <PAGE>


47      4400
                   <PAGE LISTING> <PAGE>


48      4500
<PAGE> ::= <PAGE HEAD> <PAGE BODY> <PAGE END>


49      4600
<PAGE HEAD> ::= PAGE <IDENTIFIER> ( <PAGE PARAMETER> )


50      4800
<PAGE BODY> ::= <DECLARATION LIST> <PAGE BLOCK LIST>


51      4900
<PAGE END> ::= END PAGE <IDENTIFIER>


52      5000
<PAGE PARAMETER> ::= <DIRECTION> , <MARGIN SET> <NUMBER> ,
<LOCATION>


53      5100
<LOCATION> ::= <LOCATION SIGNAL> TOP


54      5200
                   <LOCATION SIGNAL> BOTTOM


55       5300
<LOCATION SIGNAL> ::= LEFT
```

```
56      5400
                RIGHT

57      5500
                INSIDE

58      5600
                OUTSIDE

59      5700
                <NULL>

60      5800
<NUMBER> ::= <EXPRESSION>

61      5900
<DIRECTION> ::= VERTICAL

62      6000
                HORIZONTAL

63      6100
<MARGIN SET> ::= LEFT RESET ,

64      6200
                RIGHT RESET ,

65      6300
                CENTER ,

66      6400
                <NULL>

67      6500
<PAGE BLOCK LIST> ::= <STRUCTURE COMMAND LIST>
<INSTRUCTIONS>
```

```
68      6600
                <STRUCTURE COMMAND LIST> <SEGMENT LISTING>

69      6700
<STRUCTURE COMMAND LIST> ::= <NULL>

70      6800
                <STRUCTURE COMMAND LIST> <STRUCTURE COMMAND>

71      6900
<STRUCTURE COMMAND> ::= <MARGIN INSTRUCTION>

72      7000
                <FRAME INSTRUCTION>

73      7100
                <ASSIGNMENT INSTRUCTION>

74      7200
                <CHANGE INSTRUCTION>

75      7300
                <IF INSTRUCTION>

76      7400
                <WHILE INSTRUCTION>

77      7500
                <FOR INSTRUCTION>

78      7600
                <REPEAT INSTRUCTION>

79      7700
                <CASE INSTRUCTION>

80      7800
<SEGMENT LISTING> ::= <SEGMENT>
```

```
81      7900
                <SEGMENT LISTING> <SEGMENT>


82      8000
<SEGMENT> ::= <SEGMENT HEAD> <SEGMENT BODY> <SEGMENT END>


83      8100
<SEGMENT HEAD> ::= SEGMENT <IDENTIFIER> ( <SEGMENT
PARAMETER> )


84      8300
<SEGMENT BODY> ::= <DECLARATION LIST> <SEGMENT BLOCK LIST>


85      8400
<SEGMENT BLOCK LIST> ::= <STRUCTURE COMMAND LIST>
<INSTRUCTIONS>


86      9600
<SEGMENT END> ::= END SEGMENT <IDENTIFIER>


87      9700
<SEGMENT PARAMETER> ::= ALL


88      99000
                <UNIT VALUE> , <UNIT VALUE> , <UNIT VALUE> ,
<UNIT VALUE>


89      10200
<MARGIN INSTRUCTION> ::= MARGIN <MARGIN VALUE>


90      10300
<MARGIN VALUE> ::= ( <UNIT VALUE> , <UNIT VALUE> )


91      10400
                <NULL>


92      10500
<UNIT VALUE> ::= <EXPRESSION> <UNITS>
```

```
93      10600
<UNITS> ::= INCH


94      10700
                INCHES


95      10800
                <IDENTIFIER>


96      10900
<AXIS DEFINITION> ::= ( <TITLE> , <TYPE AXIS> , <MIN> ,
<MAX> , <DELTA> , <TICKS> )


97      11000
<TITLE> ::= <CHARACTER STRING>


98      11100
                <IDENTIFIER>


99      11200
<TYPE AXIS> ::= LINEAR


100     11300
                LOG


101     11400
                LOGARITHMIC


102     11500
                MONTH


103     11600
<MIN> ::= <EXPRESSION>


104     11700
                <MONTH>
```

```
105     11800
<MAX> ::= <EXPRESSION>

106     11900
                <MONTH>

107     12000
<MONTH> ::= JAN

108     12100
                FEB

109     12200
                MAR

110     12300
                APR

111     12400
                MAY

112     12500
                JUN

113     12600
                JUL

114     12700
                AUG

115     12800
                SEP

116     12900
                OCT

117     13000
                NOV
```

```
118     13100
                DEC

119     13200
<DELTA> ::= <EXPRESSION>

120     13300
<TICKS> ::= <EXPRESSION>

121     13400
<FRAME INSTRUCTION> ::= FRAME <FRAME THICKNESS>

122     13500
<FRAME THICKNESS> ( <EXPRESSION> )

123     13600
                <NULL>

124     13700
<ASSIGNMENT INSTRUCTION> ::= <SET INSTRUCTION>

125     13800
                <INPUT INSTRUCTION>

126     13900
                <OUTPUT INSTRUCTION>

127     14000
<SET INSTRUCTION> ::= SET <SET VARIABLE> = <EXPRESSION>

128     14100
                SET STRING <IDENTIFIER> = <EXPRESSION>

129     14200
                SET UNIT <IDENTIFIER> = <UNIT VALUE>

130     14300
                SET AXIS <IDENTIFIER> <AXIS SPECIFICATION>
```

```
131    14400
<SET VARIABLE> ::= <VARIABLE>


132    14700
<AXIS SPECIFICATION> ::= = <AXIS DEFINITION>


133    14800
                .  TITLE = <TITLE>


134    14900
                .  TYPE = <TYPE AXIS>


135    15000
                .  MIN = <MIN>


136    15100
                .  MAX = <MAX>


137    15200
                .  DELTA = <DELTA>


138    15300
                .  TICKS = <TICKS>


139    15400
<IF INSTRUCTION> ::= <IF HEAD> <TRUE BRANCH> <FALSE BRANCH>
END IF


140    15800
<IF HEAD> ::= IF <EXPRESSION>


141    16200
<ELSE> ::= ELSE


142    15900
<TRUE BRANCH> ::= THEN <STRUCTURE COMMAND LIST>
```

```
143     16000
<FALSE BRANCH> ::= <ELSE> <STRUCTURE COMMAND LIST>


144     16000
                   <NULL>


145     16300
<WHILE INSTRUCTION> ::= <WHILE HEAD> DO <STRUCTURE COMMAND
LIST> END WHILE


146     16500
<WHILE HEAD> ::= <WHILE> <EXPRESSION>


147     16400
<WHILE> ::= WHILE


148     16600
<FOR INSTRUCTION> ::= <FOR HEAD> DO <STRUCTURE COMMAND LIST>
END FOR


149     16700
<FOR START> ::= FOR <SET VARIABLE> = <EXPRESSION>


150     18000
<FOR HEAD> ::= <FOR START> <WAY> <BY CLAUSE>


151     16800
<WAY> ::= TO <EXPRESSION>


152     16900
                   DOWN TO <EXPRESSION>


153     17000
<BY CLAUSE> ::= BY <EXPRESSION>


154     17100
                   <NULL>
```

```
155     17200
<REPEAT INSTRUCTION> ::= <REPEAT> <STRUCTURE COMMAND LIST>
<REPEAT END>


156     17300
<REPEAT> ::= REPEAT


157     17400
<REPEAT END> ::= UNTIL <EXPRESSION> END REPEAT


158     17500
<CASE INSTRUCTION> ::= <CASE HEAD> <CASE SEQUENCE> END CASE


159     17700
<CASE HEAD> ::= CASE <VARIABLE> OF


160     17800
<CASE SEQUENCE> ::= <CASE LIST> : <STRUCTURE COMMAND LIST>


161     17900
                    <CASE SEQUENCE> <CASE LIST> : <STRUCTURE
COMMAND LIST>


162     18200
<CASE LIST> ::= <INTEGER CONSTANT LIST>


163     18300
                    <CHARACTER STRING LIST>


164     18400
                    OTHERS


165     18500
<CHARACTER STRING LIST> ::= <CHARACTER STRING>


166     18600
                    <CHARACTER STRING LIST> , <CHARACTER STRING>
```

```
167    18700
<VARIABLE> ::= <IDENTIFIER> <ARRAY SPECIFICATIONS>


168    18800
<ARRAY SPECIFICATIONS> ::= <BOUNDS>


169    18900
                <NULL>


170    19000
<INPUT INSTRUCTION> ::= INPUT <IDENTIFIER> : <SOURCE>


171    19100
<SOURCE> ::= TERMINAL


172    19200
                TAPE <INTEGER CONSTANT>


173    19300
                <DIRECT INPUT>


174    19400
<DIRECT INPUT> ::= DATA / <CONSTANT SET> /


175    19500
<CONSTANT SET> ::= <INTEGER CONSTANT SET>


176    19600
                <REAL CONSTANT SET>


177    19700
                <BOOLEAN CONSTANT SET>


178    19800
                <CHARACTER STRING>


179    19900
<INTEGER CONSTANT SET> ::= <INTEGER CONSTANT> <LIST NUMBER>
```

```
180     20000
                <INTEGER CONSTANT SET> , <INTEGER CONSTANT>
<LIST NUMBER>

181     20100
<REAL CONSTANT SET> ::= <REAL CONSTANT> <LIST NUMBER>

182     20200
                <REAL CONSTANT SET> , <REAL CONSTANT> <LIST
NUMBER>

183     20300
<BOOLEAN CONSTANT SET> ::= <BOOLEAN VALUE> <LIST NUMBER>

184     20400
                <BOOLEAN CONSTANT SET> , <BOOLEAN VALUE>
<LIST NUMBER>

185     20500
<LIST NUMBER> ::= : <INTEGER CONSTANT>

186     20600
                <NULL>

187     20700
<OUTPUT INSTRUCTION> ::= OUTPUT <EXPRESSION> : <PORT>

188     20800
<PORT> ::= TERMINAL

189     20900
                TAPE <INTEGER CONSTANT>

190     21000
                OUTPUT

191     21100
<CHANGE INSTRUCTION> ::= CHANGE <FROM SET> TO <TO SET>
```

```
192     21200
<FROM SET> ::= <CASE SET> ROMAN

193     21300
                <CASE SET> ITALIC

194     21400
                <CASE SET> SCRIPT

195     34000
<TO SET> ::= SPECIAL

196     21500
                MATH

197     21600
                <CASE SET> GREEK

198     21700
                <CASE SET> RUSSIAN

199     21800
                HEBREW

200     21900
<CASE SET> ::= UPPER

201     22000
                LOWER

202     22100
<EXPRESSION> ::= <CONDITION EXPRESSION>

203     22200
                <CONDITION EXPPESSION> <LOGIC OP> <CONDITION
EXPRESSION>
```

```
204     22300
<CONDITION EXPRESSION> ::= <SIMPLE EXPRESSION>

205     22400
                <CONDITION EXPRESSION> <CONDITION OP> <SIMPLE
EXPRESSION>

206     22500
<SIMPLE EXPRESSION> ::= <TERM>

207     22600
                + <TERM>

208     22700
                - <TERM>

209     22800
                <SIMPLE EXPRESSION> + <TERM>

210     22900
                <SIMPLE EXPRESSION> - <TERM>

211     23000
<TERM> ::= <FACTOR>

212     23100
                <TERM> * <FACTOR>

213     23200
                <TERM> / <FACTOR>

214     23300
                <TERM> MOD <FACTOR>

215     23400
                <TERM> REM <FACTOR>
```

```
216     23500
<FACTOR> ::= <PRIMARY>

217     23600
                <FACTOR> ** <PRIMARY>

218     23700
<PRIMARY> ::= NOT <PRIMARY>

219     23800
                ( <EXPRESSION> )

220     23900
                <VARIABLE>

221     24000
                <CONSTANT>

222     24100
                <CHARACTER STRING>

223     24200
                FLOAT ( <EXPRESSION> )

224     24300
                INTEGER ( <EXPRESSION> )

225     24400
                FRACTION ( <EXPRESSION> )

226     24500
                SIN ( <EXPRESSION> )

227     24600
                COS ( <EXPRESSION> )

228     24700
                TAN ( <EXPRESSION> )
```

```
229     24800
                INV SIN ( <EXPRESSION> )

230     24900
                INV COS ( <EXPRESSION> )

231     25000
                INV TAN ( <EXPRESSION> )

232     25100
                ABSOLUTE ( <EXPRESSION> )

233     25200
                STRING POINT ( <IDENTIFIER> )

234     25300
                LENGTH ( <IDENTIFIER> )

235     25400
<LOGIC OP> ::= <

236     25500
                <=

237     25600
                =

238     25700
                /=

239     25800
                >=

240     25900
                >

241     26000
<CONDITION OP> ::= AND
```

```
242     26100
                OR

243     26200
                XOR

244     26300
<CONSTANT> ::= <INTEGER CONSTANT>

245     26400
                <REAL CONSTANT>

246     26500
                <BOOLEAN VALUE>

247     26600
<INTEGER CONSTANT LIST> ::= <INTEGER CONSTANT>

248     26700
                <INTEGER CONSTANT LIST> , <INTEGER CONSTANT>

249     26800
<BOOLEAN VALUE> ::= TRUE

250     26900
                FALSE

251     27000
<INSTRUCTIONS> ::= <DRAW INSTRUCTION LIST>

252     27100
                <GRAPH INSTRUCTION>

253     27200
                <TEXT INSTRUCTION>

254     27300
                <NULL>
```

```
255     27400
<DRAW INSTRUCTION LIST> ::= <DRAW INSTRUCTION>


256     27500
                <DRAW INSTRUCTION LIST> <DRAW INSTRUCTION>


257     27600
<DRAW INSTRUCTION> ::= DRAW ARROW <ARROW STYLE> ( <UNIT
VALUE> , <UNIT VALUE> , <UNIT VALUE> , <UNIT VALUE> )


258     27700
                DRAW LINE ( <UNIT VALUE> , <UNIT VALUE> ,
<UNIT VALUE> , <UNIT VALUE> )


259     27800
<ARROW STYLE> ::= <INTEGER CONSTANT>


260     27900
                <IDENTIFIER>


261     28000
<GRAPH INSTRUCTION> ::= <GRAPH PREPARATION LIST> GRAPH
<TITLE OPTION> ( <STACK FORMATTING> <FRAME OPTION>
<INTERPOLATION TYPE> , <NUMBER PLOTS> , <XARRAY> <YARRAY> )


262     28100
<GRAPH PREPARATION LIST> ::= <NULL>


263     28200
                <GRAPH PREPARATION LIST> <GRAPH PREPARATION
INSTRUCTIONS>


264     28300
<GRAPH PREPARATION INSTRUCTION> ::= <GRID INSTRUCTION>


265     28400
                <LEGEND INSTRUCTION>
```

```
266     28500
                <AXIS INSTRUCTION>

267     28600
<GRID INSTRUCTION> ::= GRID ( <EXPRESSION> , <EXPRESSION> )

268     28700
<LEGEND INSTRUCTION> ::= LEGEND <TITLE OPTION> ( <LOCATION>
, <TITLE LIST> )

269     28800
<TITLE LIST> ::= <TITLE>

270     28900
                <TITLE LIST> , <TITLE>

271     29000
<AXIS INSTRUCTION> ::= <AXIS> = <AXIS DEFINITION>

272     29100
                <AXIS> = <IDENTIFIER>

273     29200
<AXIS> ::= XAXIS

274     29300
                YAXIS

275     29400
<TITLE OPTION> ::= <TITLE>

276     29500
                <NULL>

277     29600
<STACK FORMATTING> ::= STACK OF <INTEGER CONSTANT> ,
```

```
278     29700
                <NULL>

279     29800
<FRAME OPTION> ::= FRAMED ,

280     29900
                <NULL>

281     30000
<INTERPOLATION TYPE> ::= LINEAR

282     30100
                STEP

283     30200
                BAR

284     30300
                STACKED BAR

285     30400
                SPLINE

286     30500
                SMOOTH

287     30600
                PIE

288     30700
<NUMBER PLOTS> ::= <EXPRESSION>

289     30800
<TEXT INSTRUCTION> ::= TEXT ( <JUSTIFICATION> , <TEXT STYLE>
, <STRING NAME> , <START> , <LENGTH> , <ANGLE> <SIZE> )
```

```
290     30900
<TEXT STYLE> ::= SIMPLE

291     31000
                CARTOG

292     31100
                COMPLX

293     31200
                DUPLX

294     31300
                GOTHIC

295     31400
                SCMPLX

296     31500
                SIMPLX

297     31600
                TRIPLX

298     31700
<STRING NAME> ::= <IDENTIFIER>

299     31800
                <CHARACTER STRING>

300     31900
<START> ::= <EXPRESSION>

301     32000
                NEXT

302     32100
<LENGTH> ::= <EXPRESSION>
```

```
303     32200
                CONTINUE

304     32300
<SIZE> ::= , <UNIT VALUE>

305     32400
                <NULL>

306     32500
<ANGLE> ::= <EXPRESSION>

307     32700
<JUSTIFICATION> ::= <HORIZONTAL FORMAT> JUSTIFIED

308     32800
                <VERTICAL FORMAT> CENTERED

309     32900
<HORIZONTAL FORMAT> ::= LEFT

310     33000
                RIGHT

311     33100
                L-R

312     33200
<VERTICAL FORMAT> ::= TOP

313     33300
                BOTTOM

314     33400
                <NULL>

315     8500
<XARRAY> ::= <IDENTIFIER>
```

```
316     8600
                <DIRECT INPUT>

317     8700
<YARRAY> ::= , <IDENTIFIER>

318     8800
                , <DIRECT INPUT>

319     8900
                <null>
```

## Appendix B
## AIL Instructions

This appendix is intended to serve as a guide to the AIL instructions. Also included are statements denoting the effect of these instructions on the stack. The following notation is used:

S - STACK Pointer,
B - DISPLAY Pointer,
D - DISPLAY Stack,
I - Instruction Stack Pointer, and
C(S) - Contents of STACK at Location S.

```
LC C                    Load Constant
                        S = S + 1
                        C(S) = C

LA B,J                  Load Address
                        S = S + 1
                        C(S) = D(B) + J

LV B,J                  Load Value
                        S = S + 1
                        IF B=0
                             THEN C(S) = C(S+J)
                             ELSE C(S) = C(D(B)+J)

STD B,J,S               Store Direct
                        C(D(B)+J) = C(S)
                        S = S - 1

ST                      Store
                        C(C(S-1)) = C(S)
                        S = S - 2

CONT                    Load Contents
                        C(S) = C(C(S))
```

```
INCS                    Increment Stack Pointer
                    C(S+C(S)) = S
                    S = S + C(S)

INCS N                  Increment Stack Pointer
                    S = S + N

DECS                    Decrement Stack
                    S = S - C(S) - 1

DECS N                  Decrement Stack
                    S = S - N

NEG                     Negate
                    C(S) = -C(S)

EQ C                    Equal
                    IF C(S-1) = C(S)
                         THEN C(S-1) = 1.0
                         ELSE C(S-1) = 0.0
                    S = S - 1

LS                      Less Than
                    IF C(S-1) < C(S)
                         THEN C(S-1) = 1.0
                         ELSE C(S-1) = 0.0
                    S = S - 1

GT                      Greater Than
                    IF C(S-1) GT C(S)
                         THEN C(S-1) = 1.0
                         ELSE C(S-1) = 0.0
                    S = S - 1

NOT
                    IF C(S) = 1.0
                         THEN C(S) = 0.0
                         ELSE C(S) = 1.0
```

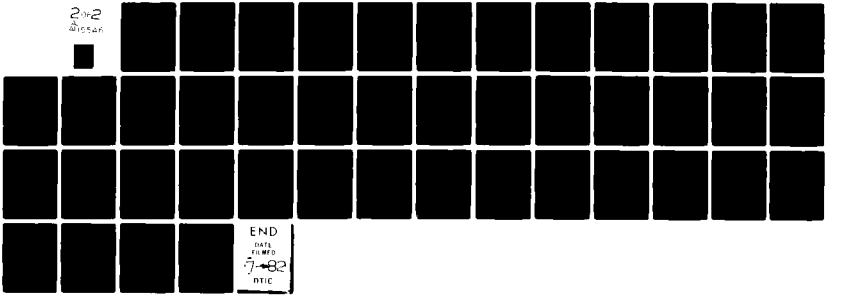
```
AND
                        IF C(S-1) = 1.0 AND C(S) = 1.0
                             THEN C(S-1) = 1.0
                             ELSE C(S-1) = 0.0
                        S = S - 1

OR
                        IF C(S-1) = 1.0 OR C(S) = 1.0
                             THEN C(S-1) = 1.0
                             ELSE C(S-1) = 0.0
                        S = S - 1

JP L                         Unconditional Jump
                        I = L

JIF L                        Jump If False
                        IF C(S) = 0.0 THEN I = L
                        S = S - 1

BE N                         Block Entry
                        C(S+1) = D(B)
                        B = B + 1
                        D(B) = S + 2
                        S = S + N + 1

EB                           Exit Block
                        S = D(B) - 2
                        B = B - 1

XOR                          Exclusive OR
                        IF C(S-1) NE C(S)
                             THEN C(S-1) = 1.0
                             ELSE C(S-1) = 0.0
                        S = S - 1

HALT                         Stop the Machine

ADD                          Addition
                        C(S-1) = C(S-1) + C(S)
                        S = S - 1
```

| | |
|---|---|
| SUB | Subtraction<br>C(S-1) = C(S-1) - C(S)<br>S = S - 1 |
| MULT | Multiplication<br>C(S-1) = C(S-1) * C(S)<br>S = S - 1 |
| DIV | Real Division<br>C(S-1) = C(S-1) / C(S)<br>S = S - 1 |
| IDIV | Integer Division<br>C(S-1) = INT(C(S-1)) / INT(C(S))<br>S = S - 1 |
| MOD | C(S-1) = MOD(C(S-1),C(S))<br>S = S - 1 |
| EXP | Exponentiation<br>C(S-1) = C(S-1) ** C(S)<br>S = S - 1 |
| INTEGER | Convert to Integer<br>C(S) = INT(C(S)) |
| FRACTION | Save Fraction<br>C(S) = C(S) - INT(C(S)) |
| SINE | C(S) = SIN(C(S)) |
| COSINE | C(S) = COS(C(S)) |
| TAN | Tangent<br>C(S) = TAN(C(S)) |

| | |
|---|---|
| INVSIN | Inverse Sine<br>C(S) = INVSIN(C(S)) |
| INVCOS | Inverse Cosine<br>C(S) = INVCOS(C(S)) |
| INVTAN | Inverse Tangent<br>C(S) = INVTAN(C(S)) |
| ABS | Absolute Value<br>IF C(S) < 0 THEN C(S) = -C(S) |
| PAGE D,M,N,L | Page Set Up |
| MAS B,J,N | Make Array Space |
| AVA B,J,N | Array Variable Address |
| START | Start Plot Routines |
| LENGTH B,J | Return Length of String<br>C(S) = LENGTH(C(S)) |
| FRAME T | Draw Frame |
| CHANGE F,T | Change Character Set |
| ARROW T | Draw Arrow<br>S = S - 5 |
| LINE T | Draw Line<br>S = S - 4 |
| GRID | Draw Grid<br>S = S - 2 |
| LEGEND T,L,N | Define Legend |

| | |
|---|---|
| GRAPH T,F,S,I | Plot Graph |
| TEXT J,S,L | Plot Text |
| MSS | Make String Space |
| ENDPLT | End Plotting |
| READ T | Read from Tape |
| PRINT T | Write to Tape |
| MSL | Make String Literal |

AD-A115 546 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOO--ETC F/G 9/2
AN INTERMEDIATE LANGUAGE AND INTERPRETER FOR THE ASGOL GRAPHICS--ETC(U)
DEC 81 K P ALBERT
UNCLASSIFIED AFIT/GCS/MA/81D-1 NL



## Appendix C

### Conditional and Looping Productions

### WHILE

<WHILE INSTRUCTION> <WHILE HEAD> DO <STRUCTURE COMMAND LIST> END WHILE

(1). Generate JP to begin label.

(2). Write end label.

<WHILE> ::= WHILE

(1). Generate end label.

(2). Generate begin label.

(3). Write begin label.

<WHILE HEAD> ::= <WHILE> <EXPRESSION>

(1). Generate JIF to end label.

### REPEAT

<REPEAT INSTRUCTION> ::= <REPEAT> <STRUCTURE COMMAND LIST> <REPEAT END>

No action is taken for this production.

<REPEAT> ::= REPEAT

(1). Generate begin label.

(2). Write begin label.

<REPEAT END> ::= UNTIL <EXPRESSION> END REPEAT

(1). Generate JIF to begin label.

## IF-THEN-ELSE

<IF INSTRUCTION> ::= <IF HEAD> <TRUE BRANCH> <FALSE BRANCH> END IF

No action is taken for this production.

<IF HEAD> ::= IF <EXPRESSION>

(1). Generate end label.

(2). Generate else label.

(3). Generate JIF to else label.

<TRUE BRANCH> ::= THEN <STRUCTURE COMMAND LIST>

No action is taken for this production.

<ELSE> ::= ELSE

(1). Generate JP to end label.

(2). Write else label.

<FALSE BRANCH> ::= <ELSE> <STRUCTURE COMMAND LIST>

(1). Write end label.

<FALSE BRANCH> ::= <NULL>

(1). Write else label.

## FOR

<FOR INSTRUCTION> ::= <FOR HEAD> DO <STRUCTURE COMMAND LIST> END FOR

(1). Generate JP to start label.

(2). Write end label.

<FOR START> ::= FOR <SET VARIABLE> = <EXPRESSION>

(1). Store expression result in variable.

(2). Generate start label.

(3). Generate end label.

<WAY> ::= TO <EXPRESSION>

No action taken for this production.

<WAY> ::= DOWN TO <EXPRESSION>

No action taken for this production.

<BY CLAUSE> ::= BY <EXPRESSION>

No action is taken for this production.

<BY CLAUSE> ::= <NULL>

No action is taken for this production.

<FOR HEAD> ::= <FOR START> <WAY> <BY CLAUSE>

(1). Load variable.

(2). Load TO expression.

(3). Test condition.

(4). Generate JIF to end label.

(5). Generate JP to start of instructions label

(6). Write start label.

(7). Load variable.

(8). Load BY expression.

(9). Add or subtract as required.

(10). Save variable.

(11). Load variable.

(12). Load TO expression.

(13). Test condition.

(14). Generate JIF to end label.

(15). Write start of instructions label.

## Appendix D

### Compiler Routines

SUBROUTINE ADDJUMP(LOC,ADDR)
This routine updates jump instructions.

SUBROUTINE CLRERR
This procedure is called to initialize the error common block.

SUBROUTINE CLRINS
This routine clears the instruction stack and resets the instruction stack pointer.

SUBROUTINE CLRLABL
This procedure clears all of the stacks used in label processing.

SUBROUTINE CLRLEX
This routine initializes the lexical variables in the common block LEXCOM.

SUBROUTINE CLRSMAN
This routine initializes all of the semantic variables in the common block SMANCOM.

SUBROUTINE CLRSTK(NUMBER)
When called by INITIAL(number = 0) this routine clears all the state stacks. When called by DOTRAN only the entry specified by number is cleared.

SUBROUTINE CLRVART
This routine is called to initialize the symbol table and its associated tables.

LOGICAL FUNCTION DIGIT(IBYTE)
This routine is very CDC dependant. It determines if IBYTE is a digit in display code.

SUBROUTINE DORED(IPROD)
This routine performs the reduction specified by IPROD.

SUBROUTINE DOTRAN(ISTA)
The transition to state ISTA is performed by this routine.

SUBROUTINE ENTRVAR(SYM1,ENTRY)
This routine is called to enter an identifier into the symbol table. The routine assumes that LOOKUP was called previously to make sure the identifier does not already exist. At the conclusion of this routine the parameter ENTRY points to the identifier's position.

SUBROUTINE ERRDIAG
This routine prints the errors that have been detected by the parser.

SUBROUTINE ERROR(INT)
This routine is called whenever an error is detected. The error number and line number are saved in the error common block.

SUBROUTINE EXITBLK(LEXICAL)
This routine is called when a block terminates. It is responsible for clearing the variables no longer needed from the symbol table.

SUBROUTINE GETLAB(LABEL)
This routine returns the next free label number.

SUBROUTINE GETLIN
This is the input routine for the parser. It gets a line from the unit inunit and puts it into the area LINEBUF. If there was an error on the previous line, line pointers are first put out to the program file.

FUNCTION IFINDR(ISTATE,ITOKEN)
If a reduction is possible when in state ISTATE looking ahead at symbol ITOKEN, the production number is returned.

FUNCTION IFINDT(IS,IT)
This function determines if a read transition can be performed when in state IS looking at symbol IT.

FUNCTION IFNDTK(IENTRY,LENGTH)
This routine searches the vocabulary for the entry IENTRY and returns its index. If it is not found a 0 is returned.

SUBROUTINE INITIAL
This routine handles all of the initialization for the system.

SUBROUTINE INITPAR
This routine sets up the system parameters.

SUBROUTINE INITTAB
This routine initializes the tables used by the parser.

SUBROUTINE INITTOK
This routine is called to initialize the basic terminals in the system.

FUNCTION IORD(ICHAR)
This function reterns the integer value of the character passed to it. Note: this function is CDC dependant.

SUBROUTINE JUMPTO(LABEL)
This routine creates an entry in BRSTACK for a jump instruction.

LOGICAL FUNCTION LETTER(IBYTE)
This routine determines if IBYTE is a letter id display code. Note: This routine is CDC dependant.

SUBROUTINE LOOKUP(SYM1,ENTRY)
This routine receives a name in the parameter SYM1 and searches the symbol table for the "first" occurence of that name. If a match is found the pointer into the symbol table for that name is returned in the parameter ENTRY; otherwise ENTRY = 0.

SUBROUTINE NEWVAR(PTR)
This routine is called to locate the first free entry in the symbol table.

SUBROUTINE NEXTINS(ARG1,ARG2,ARG3,ARG4)
This routine puts AIL instructions into the instruction stack.

FUNCTION NUMBER(IVAL)
This function returns the binary value of a number in character format. Note: this function is CDC dependant.

SUBROUTINE PARSER
This is the controling routine for the parser and thus for the entire compiler.

SUBROUTINE POP(LABEL)
This routine removes a label number from the label save stack.

SUBROUTINE PUSH(LABEL)
This routine puts a label number onto the top of the label stack.

SUBROUTINE RESOLVE(LABEL)
This routine removes label references from the BRSTACK array.

SUBROUTINE SCANNER(TOK)

This routine gets the next lexical item from the input stream.

SUBROUTINE TABDUMP

This routie is a diagnostic tool and is used to print the symbol table upon abnormal termination of the parser.

SUBROUTINE WRITLAB(LABEL)

This routine enters a label reference into the LABLSTK array. It then searches BRSTACK and resolves any references to that label.

## Appendix E

## Interpreter Routines

Since most of the routines in the interpreter execute AIL instructions, the following listing will only list the AIL instruction after the subroutine name for those routines.

```
SUBROUTINE ABSOL
     ABS

SUBROUTINE ADDIT
     ADD

SUBROUTINE ANDIT
     AND

SUBROUTINE ARROW
     ARROW T

SUBROUTINE AVA
     AVA B,J,N

SUBROUTINE BE
     BE N

SUBROUTINE CONT
     CONT

SUBROUTINE INTCOS
     COSINE
```

```
SUBROUTINE DECS
     DECS

SUBROUTINE DECSN
     DECS N

SUBROUTINE DIV
     DIV

SUBROUTINE EB
     EB

SUBROUTINE EQ
     EQ C

SUBROUTINE EXP
     EXP

SUBROUTINE FRACTN
     FRACTION

SUBROUTINE FRAME
     FRAME T

SUBROUTINE GETNEXT(NEXT)
     This subroutine gets the next instruction from the
instruction stack.

SUBROUTINE GT
     GT

SUBROUTINE HALT
     HALT

SUBROUTINE IDIV
     IDIV
```

```
SUBROUTINE INCS
     INCS


SUBROUTINE INCSN
     INCS N


SUBROUTINE INTEG
     INTEGER


SUBROUTINE INTGRID
     GRID


SUBROUTINE INVCOS
     INVCOS


SUBROUTINE INVSIN
     INVSIN


SUBROUTINE INVTAN
     INVTAN


SUBROUTINE JIF(NEXT)
     JIF L


SUBROUTINE JUMP(NEXT)
     JP L


SUBROUTINE LA
     LA B,J


SUBROUTINE LC
     LC C


SUBROUTINE INTLEG
     LEGEND T,L,N,G


SUBROUTINE LINE
     LINE T
```

```
SUBROUTINE LENGTH
     LENGTH


SUBROUTINE LS
     LS


SUBROUTINE LV
     LV B,J


SUBROUTINE MAS
     MAS B,J,N


SUBROUTINE MULT
     MULT


SUBROUTINE NEG
     NEG


SUBROUTINE BOOLNOT
     NOT


SUBROUTINE BOOLOR
     OR


SUBROUTINE INTPAGE(PAGENUM)
     PAGE D,M,N,L


SUBROUTINE PAGEPOS(XPOS,YPOS,LOCAT,ALENG)
     This subroutine calculates the page number position.


SUBROUTINE INTSINE
     SINE


SUBROUTINE ST
     ST


SUBROUTINE STD
     STD B,J
```

```
SUBROUTINE SUB
     SUB


SUBROUTINE TAN
     TAN


SUBROUTINE XOR
     XOR
```

# Appendix E

## User's Guide

This appendix is intended to serve solely as a users guide and not as a tutorial on the use of ASGOL. It is hoped that by studying the examples of Chapter 6 and by referencing the appropriate instructions in this appendix an understanding of the use of ASGOL can be obtained. To facilitate the use of this guide the instructions have been divided into six sections as follows:

(1). Block structutre instructions,

(2). Constant and variable declarations,

(3). Operating instructions,

(4). Graphing instructions,

(5). Graph set-up instructions, and

(6). Arithmetic operations.

Before discussing specific instructions it is necessary to define some common symbols that are used often.

<ID> - This symbol represents a sequence of letters and digits with the following restrictions:

(1). The first character must be a letter (A-Z),

(2). Only letters and digits (0-9) are allowed,

(3). The length must be less than or equal to 10, and

(4). It cannot be a reserved word.

<EXP> - This symbol represents an expression and can have either a real, integer, character, or boolean value.

<UNIT> - This symbol can represent one of three forms; <EXP> INCH, <EXP> INCHES, or <EXP> <ID>.

<VARIABLE> - This symbol represents an identifier and can be an array specification.

<INTEGER> - This represents an integer constant: 1, 2, 5, etc.

## Block Structure Instructions

PROGRAM <ID>

END PROGRAM <ID> .

These two instructions are required for all programs. The first must be at the beginning and the second must be at the end. The <ID> refers to the name of the program and it cannot be used anywhere else within the program.

Note: The <ID> in both instructions must be the same.

SECTION <ID>

END SECTION <ID>

Within a program any number of sections may be defined. Each must have a unique name and each must begin with the first instruction and end with the second. Because of the block structure of the language all data defined in one section will not be known by any other section. This allows constants and variables with only limited usefullness to be defined for only a limited time.

Note: The <ID> in both instructions must be the same.

PAGE <ID> ( <DIRECTION> , <MARGIN> <NUMBER> , <LOCATION> )

END PAGE <ID>

Within a section if any are defined or alone otherwise any number of pages may be defined. Every page must have a unique name and must begin with the first instruction. This instruction has four parameters that are defined as follows:

<DIRECTION> - Determines the physical size of the page.

VERTICAL - 8 1/2 X 11 INCHES

HORIZONTAL - 11 X 8 1/2 INCHES

<MARGIN> - This parameter is optional and is used to determine where on the page the grace (binding) margin is to be located. If used this parameter must be followed by a comma.

LEFT RESET - 1" margin on upper, lower, and right sides; 1 1/2" on left side.

RIGHT RESET - 1" margin on upper, lower, and left sides; 1 1/2" on right side.

CENTER - 1" margin on all sides.

<NUMBER> - This parameter can be either an integer value, a real value, or a character string. It is the number that is printed on the page.

Note: (1). If an integer value 0 is used no number will be printed.

(2). If a character string is used a maximum of 20 characters is allowed. If more than 20 are used only the first 20 will be printed.

<LOCATION> - This parameter determines where on a page the page number will be printed.

LEFT TOP - The number will begin directly above the left margin.

RIGHT TOP - The number will end directly above the right margin.

INSIDE TOP - The number will either begin or end directly above the binding margin depending on the side that the margin is on.

OUTSIDE TOP - The number will either begin or end directly above the margin opposite the binding margin.

TOP - The number will be centered at the top of the page.

LEFT BOTTOM - The number will begin directly below the left margin.

RIGHT BOTTOM - The number will end directly below the right margin.

INSIDE BOTTOM - The number will either begin or end directly below the binding margin depending on the side the margin is on.

OUTSIDE BOTTOM - The number will either begin or end directly below the margin opposite the binding margin.

BOTTOM - The number will be centered at the bottom of the page.

Note: (1). If the margin parameter is omitted the default is LEFT RESET.

(2). Even though a 0 is entered to indicate no page number is to be printed, one of the location options must still be specified.

(3). INSIDE TOP, OUTSIDE TOP, INSIDE BOTTOM, and OUTSIDE BOTTOM cannot be used with the margin parameter CENTER.

(4). Numbers printed at the top of the page are 12" above the top margin and numbers printed at the bottom of the page are 12" below the bottom margin.

All pages must end with the instruction

END PAGE <ID>.

SEGMENT <ID> <PARAMETERS>

END SEGMENT <ID>

Within each page any number of segments can be defined. Like the PROGRAM, SECTION, and PAGE blocks they must each have a unique name. The segment is the lowest level that can be obtained and it must begin with the first instruction. This instruction can have up to four parameters as follows:

<PARAMETERS> - This parameter is used to define the amount of the page that the segment is to cover.

(ALL) - The segment area is the same as the page area.

(<UNIT> , <UNIT> , <UNIT> , <UNIT>) - These four values represent the area of the segment by defining the distance from the page origin to the beginning and the end

of the area in each direction. The first value is the distance to the start in the X direction and the second value is the distance to the end. Similarily the third parameter is the distance to the start in the Y direction and the fourth is the distance to the end.

Note: (1). Value 2 must be greater than value 1 and value 4 must be greater than value 3.

(2). All values must be greater than 0 and must be contained within the dimensions of the page.

All segments must end with the instruction

END SEGMENT <ID>

where <ID> is the same as the name specified when the segment was defined.

## Constant and Variable Declarations

### DECLARE

This instruction must begin any declaration of constants or variables. It can be used only once per block.

## CONSTANT

This instruction is used when constants are desired. It must follow the DECLARE statement and it also can only be used once per block.

<ID> = <TYPE>

This statement is the form of the constant declarations. Any number of these instructions can follow the CONSTANT statement. If, however, more than one constant is declared the names must be unique. The value of this form is that constants cannot be modified within the program while variables can.

<TYPE> - This parameter represents the value that the constant is to have. It can be an integer value, a real value, a character string, or the boolean values TRUE or FALSE.

## VARIABLE

This instruction is used in the definition of variables. It must follow all constant declarations, if any, and can only be used once per block.

<ID> : <TYPE>

<ID>,<ID> : <TYPE>

These two forms are used to define variables. Any number of statements may be used and the two forms can be used in any combination. The first form is used for a single variable while the second is used if several variables of the same type are desired. These instructions must follow a VARIABLE statement.

<TYPE> - This parameter determines what kind of variable is being defined and can have any of the following values: INTEGER; REAL; BOOLEAN; CHARACTER; AXIS; UNIT; STRING(size); or ARRAY( ) OF INTEGER, REAL, BOOLEAN, or CHARACTER.

Note: Constants and variables can be defined in any of the segments, pages, sections, or even in the program block. Wherever defined, they can only be used in the block in which they are defined and in any block defined within that block. For example, the sequence

```
PROGRAM TEST
    DECLARE CONSTANT A = 10.5
PAGE EXAMPLE
```

would result in the constant A being defined. Further since the page EXAMPLE is a block within the program block A could be used by the block.

## Operating Instructions

These instructions are responsible for the manipulation of data within the ASGOL program. Whenever the representation <COMMANDS> is used it refers to one of these instructions.

### MARGIN

MARGIN (<UNIT>,<UNIT>)

This instruction can have one of two forms and is used to set a margin relative to the page or segment area. The first form will result in a margin value of 5% of the area dimension in both directions. If specific values are desired the second form allows the exact values to be specified for both the X and the Y directions. The first

value is the X margin while the second is the Y margin.

FRAME

FRAME (value)

This instruction is used to draw a frame around the page or segment area. If the first is used the frame will have a thickness of one line. If a greater thickness is needed, the second form is used. The value or expression result in parentheses represents the number of lines in the frame. This is an integer value and can be any number in the range 0-25.

SET <VARIABLE> = <EXP>

This instruction is used to modify any variables other than UNIT, STRING, or AXIS. <VARIABLE> can be any other type including array if desired. <EXP> represents an arithmetic expression, a variable or a constant.

SET STRING <ID> = <EXP>

This instruction is used only to modify string variables. <ID> must be the name of a string and <EXP> must be a string expression, a string variable, or a string constant.

SET UNIT <ID> = <UNIT>

This instruction is used to define UNIT variables. These variables can be defined in terms of INCHES or of another unit variable. For example, if the unit variable FEET had been declared as 12 INCHES then the following statement could be used to define METERS.

SET UNIT METERS = 3.281 FEET

Through this type of definition any units that are needed can be declared removing the need for manual conversions.

SET AXIS <ID> = <DEF>

This instruction is used to define or modify an axis variable. <DEF> is defined as follows.

(<TITLE>,<TYPE>,<MIN>,<MAX>,<DELTA>, <TICKS>) - This form is used if all six parameters of the axis are defined at the same time.

<TITLE> - A character string or string variable that is 80 characters or less.

<TYPE> - One of four values LINEAR, LOG, LOGARITHMIC, or MONTH, that describes the values defined by the axis.

<MIN> - This value is either an expression representing the starting value for LINEAR or LOG axes or the name of a month (JAN-DEC) for month type axes.

<MAX> - This value has the same type as the MIN value and it represents the end point of the axis.

<DELTA> - This is an expression representing the number of incremental steps of the axis starting with 1 at the minimum value.

<TICKS> - This value is an expression representing the number of marks placed evenly between each incremental step of the axis.

SET AXIS <ID> . TITLE = <TITLE>

SET AXIS <ID> . TYPE = <TYPE>

SET AXIS <ID> . MIN = <MIN>

SET AXIS <ID> . MAX = <MAX>

SET AXIS <ID> . DELTA = <DELTA>

SET AXIS <ID> . TICKS = <TICKS>

These instructions are used to define or modify a particular parameter of an axis variable. The values have the same meaning as was discussed in the previous instruction.

IF <EXP> THEN <COMMANDS> END IF

IF <EXP> THEN <COMMANDS> ELSE <COMMANDS> END IF

The IF statement can take one of two forms depending on whether the ELSE clause is desired or not. If the expression is true the THEN clause is executed, otherwise the ELSE clause, if present, is executed. If no ELSE clause is present execution will continue with the next instruction.

WHILE <EXP> DO <COMMANDS> END WHILE

As long as the expression is true in this instruction the commands will be executed.

FOR <VARIABLE> = <EXP> <WAY> <EXP> <BY> DO <COMMANDS> END FOR

This statement is used to execute a loop a specific number of times.

<WAY> - This parameter determines whether the loop variable is incremented or decremented. It can have one of the following two values.

TO - The BY expression is added to the variable on each iteration of the loop.

DOWN TO - The BY expression is subtracted from the variable on each iteration of the loop.

<BY> - This parameter is optional. If omitted a value of 1 is assumed.

BY <EXP> - This expression is used as the value for each loop iteration. It is either added to or subtracted from the loop variable depending on the value of the parameter <WAY>.

REPEAT <COMMANDS> UNTIL <EXP> END REPEAT

This instruction will repeat the commands until the expression is true.

CASE <VARIABLE> OF

This instruction provides a multi-path branching capability for ASGOL. This must be the first statement.

<INTEGER>,<INTEGER> : <COMMANDS>

<CHARACTER STRING> : <COMMANDS>

OTHERS : <COMMANDS>

These instructions are used to define the branches of the CASE instruction. If the integer constant form is used a string of integers can be put into one instruction. Any number of instructions can be used in one CASE statement. If the value of the variable is equal to one of the integers that instruction is executed, otherwise the OTHERS statement,if included, is executed.

Note: (1). Integer and character strings cannot be used together within the same CASE statement.

(2). Only one character string is allowed per instruction.

(3). OTHERS instruction can be used with either form.

END CASE

This instruction must be the last statement in the CASE instruction.

INPUT <ID> : <SOURCE>

This instruction is used to input data to the program. the source for this data as follows.

TERMINAL - A value is read from the terminal.

TAPE <INTEGER> - A value is read from the tape file specified by <INTEGER>.

<DIRECT INPUT> - This parameter allows data to be specified in the in the instruction and has the value

DATA /<VALUES>/

where <VALUES> can be integer, real, boolean, or character constants. These values can be in the form of a string (10, 5, 4, 3) or if multiple copies of one value is desired the

following format can be used:

DATA 10.1,5.2:3

In this case four values are defined 10.1, 5.2, 5.2, and 5.2.

OUTPUT <EXP> : <DESTINATION>

This instruction is used to write the results of the expression to the destination specified by <DESTINATION>. This parameter can have one of the following values.

TERMINAL - The value is written to the terminal.

TAPE <INTEGER> - The value is written to the tape file specified by <INTEGER>.

OUTPUT - The value is written to the standard output printer file.

CHANGE <FROM> TO <TO>

This instruction is used to change one of the six character sets that DISSPLA allows to be active at one time. DISSPLA has other character sets that could be useful. The two sets are defined as follows:

<FROM> - UPPER ROMAN, LOWER ROMAN, UPPER ITALIC,, LOWER ITALIC,UPPER SCRIPT,LOWER SCRIPT.

<TO> - SPECIAL, MATH, UPPER GREEK, LOWER GREEK,

UPPER RUSSIAN, LOWER RUSSIAN, HEBREW.

Graphing Instructions

DRAW ARROW <STYLE> (<UNIT>,<UNIT>,<UNIT>,<UNIT>)

This instruction is used to draw arrows anywhere within a PAGE or SEGMENT area. Any number of these arrows can be drawn in one plot. The first two unit parameters represent the X and Y position of the starting point and the last two parameters represent the ending point of the arrow. <STYLE> represents an integer value used to indicate the type and position of the arrow heads as shown in the DISSPLA manual (Ref 2:PART B 21-7).

DRAW LINE (<UNIT>,<UNIT>,<UNIT>,<UNIT>

This instruction is used to draw lines in the plotting area. Like the ARROW instruction the first two parameters are the X and Y coordinates of the starting point and the last two parameters are the coordinates of the ending point of the line. There is no restriction to the number of LINE instructions that can be included within a plot.

Note: (1). Both endpoints must be within the plotting area.

(2). Any combination of ARROW and LINE instructions is valid.

GRAPH <TITLE> (<STACK><FRAME><TYPE>, <POINTS>,<XARRAY><YARRAY>)

This instruction is the main graphing instruction for ASGOL. The parameters are defined below. Only one GRAPH instruction is allowed for a plot.

<TITLE> - This parameter is optional but if used it is a string name or a string literal of 20 characters or less.

<STACK> - This parameter is also optional. If used the form is

STACK OF <INTEGER>,

This feature allows up to 5 plots to be stacked within one PAGE or SEGMENT.

<FRAME> - Another optional parameter that when used has the form

FRAMED ,

It results in a frame being drawn along the axes of the plot.

<TYPE> - This parameter specifies the kind of plot that is desired as follows:

LINEAR - Both the X and Y axes are linear.

STEP - Steps are plotted at each data point.

BAR - A bar graph is plotted.

STACKED BAR - If more than one set of bars is plotted, they will be stacked to save space.

SPLINE - Spline smoothing will be used on the data points.

SMOOTH - Straight line smoothing will be used on the data points.

PIE - A pie graph will be drawn.

<POINTS> - This parameter is an expression representing the number of data points to be plotted.

<XARRAY> - Either an array name or direct input as defined in the INPUT instruction that represents the X coordinates of the data points to be plotted.

<YARRAY> - This parameter is required for all plot types except PIE plots. It is defined the same as <XARRAY> and contains the Y coordinates of the data points.

TEXT (<JUSTIFICATION>,<STYLE>,<NAME>,
<START>,<LENGTH>,<ANGLE><SIZE>)

This is the text processing instruction of ASGOL. The parameters are defined as follows:

<JUSTIFICATION> - This parameter specifies the justification of the text according to the parameters below.

LEFT JUSTIFIED - All lines except for paragraph indentations are flush with the left margin.

RIGHT JUSTIFIED - All lines are flush with the right margin.

L-R JUSTIFIED - All lines are flush with both margins with blanks inserted as needed.

TOP CENTERED - All lines will be centered with the first line on the top margin.

BOTTOM CENTERED - This is the same as TOP CENTERED except the last line ends on the bottom margin.

CENTERED - All lines will be centered with the first line starting on the top margin. All other lines will be spaced to allow the last line to end on the bottom margin.

<STYLE> - This parameter is used to select the print style from the following: SIMPLE, CARTOG, COMPLX, DUPLX, GOTHIC, SCMPLX, SIMPLX, and TRIPLX.

<NAME> - This parameter is either a character string or the string name of the text to be plotted.

<START> - One of two forms is valid for this parameter, <EXP> or NEXT. It indicates the position in the string to start printing. <EXP> is an expression between 1 and the length of the string. When NEXT is specified printing will start with the next character if part of the string was previously printed, otherwse printing starts with the first character.

<LENGTH> - This is an indicator of the number of characters to be printed. If an expression is used it defines the exact number of characters. If, however, the value CONTINUE is used the string will be printed until the end is reached or until the end of the plot area is encountered. This facility removes the necessity for counting strings.

<ANGLE> - This parameter is an expression used to rotate the text relative to the origin of the plot.

<SIZE> - This is an optional parameter that specifies a character height for the string. If omitted , the default height of .14 inches is used.

## Graph Set Up Instructions

GRID (<EXP>,<EXP>)

This instruction is used to draw a background grid on a plot. The first expression is the number of lines per inch in the X direction and the second expression is the number of lines in the Y direction. Only one GRID instruction is allowed per plot.

LEGEND <TITLE> (<POSITION>,<LINE>,<LINE>)

This instruction defines a legend for a plot. The parameters are defined below.

<TITLE> - This is an optional parameter which can be used to change the title of the legend block. If omitted, the title "LEGEND" will be used otherwise the character string or string name will be used.

<POSITION> - This position determines where in the plot the legend block will be. Care should be taken with this placement since no points are plotted within the block. The following positions are valid: LEFT TOP, RIGHT TOP, INSIDE TOP, OUTSIDE TOP, TOP, LEFT BOTTOM, RIGHT BOTTOM, INSIDE BOTTOM, OUTSIDE BOTTOM, and BOTTOM.

<LINE> - For each line in the legend a parameter must be included in the order to be printed. This parameter can either be a character string or a string variable and must be 20 characters or less.

Note: For PIE graphs these parameters represent the titles that are written in each slice of the pie.

<AXIS> = <DEF>

This instruction is used to define the X and Y axes for the plot. The parameters are defined as follows.
<AXIS> - This parameter has one of two values, XAXIS or YAXIS, depending on which axis is being defined.
<DEF> - There are two forms to this parameter. It can be an axis variable name or it can be a specific definition of all the axis parameters as shown in the SET AXIS instruction.

Arithmetic Operations

Arithmetic operators - The following operators are valid in arithmetic expressions:

+,-,*,/,MOD,REM,**

Functions - Several functions are available as defined below.

FLOAT (<EXP>) - Converts an integer number to a real number.

INTEGER (<EXP>) - Converts a real number to an integer number.

FRACTION (<EXP>) - Takes a real number and returns the fractional portion.

SIN (<EXP>) - Computes the sine of the expression.

COS (<EXP>) - Computes the cosine of the expression.

TAN (<EXP>) - Conputes the tangent of the expression.

INV SIN (<EXP>) - Computes the inverse sine of the expression.

INV COS (<EXP>) - Computes the inverse cosine of the expression.

INV TAN (<EXP>) - Computes the inverse tangent of the expression.

ABSOLUTE (<EXP>) - The absolute value of the expresion is returned.

STRING POINT (<ID>) - The position of the next character to be printed in a string is calculated.

LENGTH (<ID>) - This function returns the lenght of the string denoted by <ID>.

Logic Operators - The following logic operators are valid in conditional expressions:

<,<=,=,/=,>=,>.

Boolean Operators - Four boolean operators are allowed in ASGOL. They are:

AND, OR, XOR, and NOT.

# VITA

Kevin P. Albert was born on 31 July 1951 in Houlton, Maine. He graduated from Houlton High School in 1969 and attended the University of Maine, Orono, Maine, from which he received a Bachelor of Arts degree in Mathematics in January 1973. After graduation he was employed as a computer programmer for Dun & Bradstreet, Inc., New York, New York. He entered the Air Force in December 1975, and received his commission from Officers Training School in May, 1977. He served as a computer programmer for Detachment III of the Air Force Flight Test Center until entering the School of Engineering, Air Force Institute of Technology, in June 1980. He is a member of Tau Beta Pi.

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In an effort to make ASGOL (ALGOL-Structured Graphics Oriented Language) more powerful, conditional and looping instructions were added to the language. To do this the existing interpreter system was converted to a compiler/interpreter system. An intermediate language was designed as the compiler output and thus the source language for the interpreter.

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